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The NASA MSFC Earth Global Reference Atmospheric Model—2007 Version

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LIST OF ACRONYMS AND SYMBOLS

AE	atmosphere explorer
AFGL	Air Force Geophysics Laboratory
AFMS	Air Force Mid-latitude Summer data
AFMW	Air Force Mid-latitude Winter data
AFSS	Air Force Sub-arctic Summer data
AFSW	Air Force Sub-arctic Winter data
AFTR	Air Force Tropical data
AMPS	Automated Meteorological Profiling System
Ar	argon
ASCII	American standard code for information interchange
CO	carbon monoxide
CO_2	carbon dioxide
CH_4	methane
CD-ROM	compact disc-read only memory
CIRA	Cooperative Institute for Research in the Atmosphere
COMNAVOCEANCOM	Commander, Naval Oceanography Command
COSPAR	Committee on Space Research
ECMWF	European Center for Medium-Range Weather Forecasts
EOR	end of record
EUV	extreme ultraviolet

GGUAS	Global Gridded Upper Air Statistics
GPS	Global Positioning System
GRAM	Global Reference Atmospheric Model
GRS	Geodetic Reference System
GUACA	Global Upper Air Climatic Atlas
H_2O	water vapor
He	helium
H	hydrogen
HWM	Harmonic Wind Model
IAU	International Astronomical Union
IERS	International Earth Rotation and Reference System
JB	Jacchia-Bowman
KSC	Kennedy Space Center
LaRC	Langley Research Center
lat-lon	latitude-longitude
MAP	Middle Atmosphere Program
MET	Marshall Engineering Thermosphere
MG2	double-ionized magnesium
MSFC	Marshall Space Flight Center
N_2	nitrogen
N_2O	nitrous oxide

LIST OF ACRONYMS AND SYMBOLS (Continued)

NAVOCEANCOM DET	Naval Oceanography Command Detachment
NCDC	National Climatic Data Center
NESDIS	National Environmental Satellite Data and Information Service
NOAA	National Oceanic and Atmospheric Administration
NRL MSIS	Naval Research Labs Mass Spectrometer, Incoherent Scatter Radar Extended Model
O	atomic oxygen
O_2	molecular oxygen
PC	personal computer
ppbv	parts per billion by volume
ppmv	parts per million by volume
RRA	range reference atmosphere
SGI	Silicon Graphics Incorporated
TM	technical memorandum
TOGA	tropical ocean global atmosphere
UTC	universal time coordinated
WGS	World Geodetic System
WMO	World Meteorological Organization

NOMENCLATURE

A	local wave amplitude
$A(z)$	data set, amplitude
$B(z)$	data set
C	faired value
L	local vertical correlation scale (small-scale perturbation)
L_{avg}	average scale size
L_h	horizontal scale parameter
L_{max}	maximum scale size
L_{min}	minimum scale size
L_z	vertical scale parameter
P_{sev}	probability of severe perturbations
P_{tail}	tail probability of a Gaussian distribution
R	gas constant
$T(z)$	temperature
V	variable available on two-dimensional grid
c	concentrations
f_{non}	factor for variance of non-severe perturbation
f_{sev}	factor for variance of severe perturbation
g	acceleration of gravity
$p(z)$	pressure

NOMENCLATURE (Continued)

q	Gaussian-distributed random number
r	auto-correlation value
R_C	cross-correlation
r_t	rate of change
s_y	stationary perturbation
t	year
x	longitude, height, or log pressure
$\mathbf{x}$	vector position
$\mathbf{x}'$	trajectory position
y	latitude, pressure, density, or temperature parameter
y_m	monthly mean value
z	heights
z_y	zonal-mean value
δt	time step
δh	horizontal step
δz	vertical step
γ	temperature gradient
λ	local vertical wavelength
μ	normalized variant
σ	local standard deviation (small-scale perturbation)
σ_L	standard deviation of small-scale perturbation

NOMENCLATURE (Continued)

σ_T	total perturbation magnitude
σ^2	total variance of small-scale perturbation
τ	time scale
$\rho(z)$	density

TECHNICAL MEMORANDUM

THE NASA MSFC EARTH GLOBAL REFERENCE ATMOSPHERIC MODEL—2007 VERSION

1. INTRODUCTION

1.1 Background and Overview

Reference or standard atmospheric models have long been used for design and mission planning of various aerospace systems. The NASA/Marshall Space Flight Center (MSFC) Global Reference Atmospheric Model (GRAM) was developed in response to the need for a design reference atmosphere that provides complete global geographical variability, and complete altitude coverage (surface to orbital altitudes) as well as complete seasonal and monthly variability of the thermodynamic variables and wind components. A unique feature of GRAM is that, in addition to providing the geographical, height, and monthly variation of the mean atmospheric state, it includes the ability to simulate spatial and temporal perturbations in these atmospheric parameters (e.g. fluctuations due to turbulence and other atmospheric perturbation phenomena). A summary comparing GRAM features to characteristics and features of other reference or standard atmospheric models, can be found in "Guide to Reference and Standard Atmosphere Models."[1]

The original GRAM[2] has undergone a series of improvements over the years with recent additions and changes.[3–7] The software program is called Earth-GRAM2007 to distinguish it from similar programs for other bodies (e.g. Mars, Venus, Neptune, and Titan). However, in order to make this Technical Memorandum (TM) more readable, the software will be referred to simply as GRAM07 or GRAM unless additional clarity is needed. Section 1 provides an overview of the basic features of GRAM07 including the newly added features. Section 2 provides a more detailed description of GRAM07 and how the model output is generated. Section 3 presents sample results. Appendices A and B describe the Global Upper Air Climatic Atlas (GUACA) data and the Global Gridded Upper Air Statistics (GGUAS) database. Appendix C provides instructions for compiling and running GRAM07. Appendix D gives a description of the required NAMELIST format input. Appendix E gives sample output. Appendix F provides a list of available parameters to enable the user to generate special output. Appendix G gives an example and guidance on incorporating GRAM07 as a subroutine in other programs such as trajectory codes or orbital propagation routines.

1.2 Basic Description of the Global Reference Atmospheric 07 Model

As are earlier versions, GRAM07 is a mixture of empirically-based models that represent different altitude ranges (and the geographical and temporal variations within these altitude ranges). In addition to using GUACA compact disc-read-only memory (CD-ROM) data of Ruth et al.[8] for the lower altitude region (0 to 27 km), GRAM07 alternately allows optional use of an American Standard Code for Information Interchange (ASCII)-formatted GGUAS database for this height region.

The GUACA (or GGUAS) data cover the altitude region from 0 to 27 km (in the form of data at the surface and at constant pressure levels from 1,000 to 10 mb). The middle atmospheric region (20 to 120 km) data set is compiled from Middle Atmosphere Program (MAP) data[9] and other sources referenced in the GRAM-90 and GRAM-95 reports.[5,6] For the highest altitude region (above 90 km), the user now has the choice of three thermosphere models (see section 1.3.4). Fairing techniques provide smooth transition between the altitude regions. Unlike interpolation (used to "fill in" values across a gap in data), fairing is a process that provides a smooth transition from one set of data to another in overlapping regions (e.g. 20 to 27 km for GUACA/GGUAS and MAP data and 90 to 120 km for MAP data and the thermosphere models). Figure 1 provides a graphical summary of the data sources and height regions.

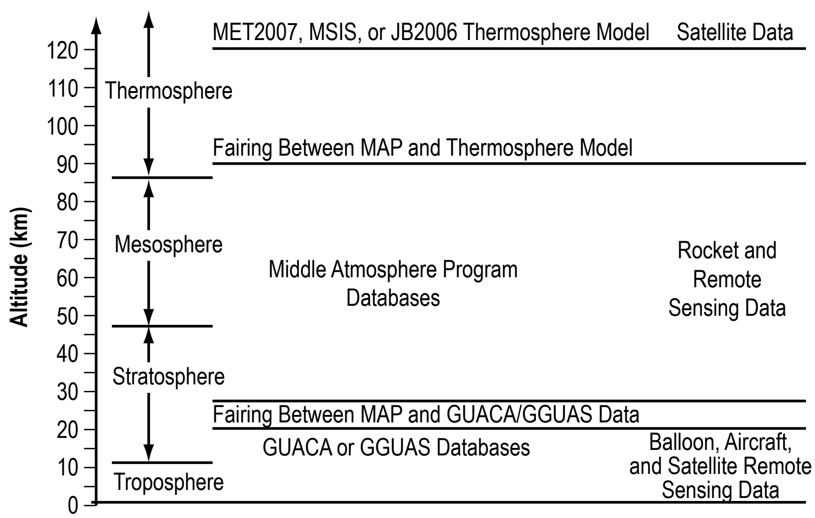

Figure 1. Schematic summary of the atmospheric regions in the GRAM07 program, sources for the models, and data on which the mean monthly GRAM07 values are based.

Beginning with GRAM-95, the model provides estimates of atmospheric species concentrations for water vapor (H_2O), ozone (O_3), nitrous oxide (N_2O), carbon monoxide (CO), methane (CH_4), carbon dioxide (CO_2), nitrogen (N_2), molecular oxygen (O_2), atomic oxygen (O), argon (Ar), helium (He), and hydrogen (H). The Marshall Engineering Thermosphere (MET) model (as well as two new thermosphere models, added in GRAM07) provide the species concentrations for

N_2, O_2, O, A, He, and H above 90 km. Air Force Geophysics Laboratory (AFGL) atmospheric constituent profiles[10] are also used extensively for the constituents to a 120-km altitude.

The GUACA data set provides water vapor data from the surface to the 300-mb pressure level. The NASA Langley Research Center (LaRC) water vapor climatology[11] includes H_2O values from a 6.5- to a 40.5-km altitude. The MAP data[12] include H_2O data from the 100- to 0.01-mb pressure level. Other details of the species concentration model are given in sections 1.4 and 2.4 of Justus et al.[6]

1.3 Summary of New Model Features

1.3.1 Revised Perturbation Model

Planetary scale Rossby waves have periods of several days, and at longer wavelengths, may produce quasi-stationary wave patterns. Baroclinic instability of the Rossby waves produces the familiar patterns of fronts, cyclones, and anticyclones of tropospheric weather. Atmospheric tides, produced primarily by solar heating of water vapor in the troposphere and ozone in the stratosphere, have planetary-scale wavelengths and predominately diurnal and semidiurnal periods. Time-of-day variations due to atmospheric tides tend to amplify with altitude. The upper atmosphere section of GRAM07 treats the major aspects of time-of-day variations. Surface heating produces convective circulations that can lead to thunderstorms. Instability or other mechanisms can produce organized lines of thunderstorms and groups of thunderstorms called a mesoscale convective complex. Atmospheric gravity waves may be produced by orographic flow effects or may be triggered by thunderstorms, tropical storms, or other disturbances. As with tides, gravity waves tend to amplify with height, but since they are more irregular in their nature, they cannot be modeled explicitly. Atmospheric turbulence occurs at relatively small scales and can be triggered by surface heating, orographic effects, or instability processes produced by gravity waves, tides, or jet stream shears associated with the Rossby waves.

In GRAM-90, all of these processes were parameterized stochastically using a two-scale perturbation model. A smaller scale parameter was used to represent such small-scale processes as turbulence, mesoscale storms, and gravity waves while a larger scale parameter was used to represent such large-scale processes as Rossby waves, cyclones and anticyclones, and tides. Each of these two-scale parameters was used, in the sense of a spectral integral scale, to characterize a spectrum that spans a significant range of wavenumbers. In GRAM-90 these scale parameters were assumed to be altitude- and latitude-dependent only.

A new, variable-scale, small-scale perturbation model was introduced in GRAM-95. Through stochastic variation of the value of the small-scale parameter, this model incorporates many of the features of the atmospheric turbulence model of Justus et al.[13] In particular, the effects of intermittency and the tendency of turbulence to appear in patches or layers, are incorporated as an option. The modeling approach, described more fully in section 2.6 of Justus et al.[6] results in a simpler implementation incorporating fewer simulation parameters than the original model.[13]

The time-series simulations of the variable length scale were introduced and used to categorize the turbulence as normal (light-to-moderate) or disturbed (severe) in GRAM-99. The turbulence (wind, density, temperature, etc.) is in disturbed conditions whenever the length scale drops below a prescribed "minimum" value.[6] The probability, *P*, of being in disturbed conditions is taken from statistics in NASA TM 4168,[13] and varies from 1 to 2.5 percent near the surface to about 0.15 percent near a 25-km altitude to about 2 percent near 75-km and back to about 1 percent above a 120-km altitude. To obtain these appropriate probability values, the values for standard deviation of the length scales were modified in the "atmosdat" data file (described in section 4.2). A wave model for the large scale was introduced in GRAM-99 using a fixed amplitude cosine function.

Several changes/additions have been made in the perturbation model in GRAM07. These include:

(1) A new feature to update atmospheric mean values without updating perturbation values. This option can be beneficial in trajectory codes that use fast-calling frequencies. In cases for slow-moving vehicles the spatial step may be so small that adjacent points are highly correlated and do not recover the appropriate statistics. In GRAM07, the mean values can be updated at one frequency while the perturbations are computed at a more appropriate interval. Another application is in trajectory codes that use Runge-Kutta (or other predictor-corrector) techniques that iterate before determining a final position. Earlier versions of GRAM would correlate each subsequent guess position instead of just the first and final positions. With this new feature, proper correlations can be obtained. This new feature is illustrated in example trajectory program trajopts. (See appendix G).

(2) Large-scale perturbations now have randomized amplitude, wavelength, phase, and period. In the previous version of GRAM the large-scale perturbations were modeled with a cosine function of fixed amplitude. This limited the large-scale perturbations to square-root[2] (=1.4) times the large-scale standard deviations. By using a randomized amplitude, excursions beyond this limit were realized. When this modification was combined with refinements in the small-scale perturbation model, the dispersions appeared to be more Gaussian in distribution. Figure 2 shows the probability distribution of air density when patches of severe turbulence have been disabled (designated Patchy Off), but allowing for moderate turbulence. The GRAM07 output (shown as points) is in good agreement with a Gaussian distribution (solid line). For this particular run, the maximum (minimum) deviation was 3.38 (–3.35) standard deviations.

(3) The ability to simulate large-scale, partially-correlated perturbations as they progress over time for a few hours to a few days. GRAM07 comes with a program called corrtraj that is used to simulate a sequence of profiles over a period of (typically) a few hours to a few days. Time variation of wave phases of the large-scale perturbation model ensures that each profile in the time sequence has appropriate large-scale correlation with the previous profile in the sequence. Specific correlations between small-scale perturbations in the profiles are maintained by perturbation correlation routines built into the corrtraj driver code. Program corrtraj is meant to be run interactively, with input values requested for: (1) number of profiles to generate, (2) time step (hours) between successive profiles, (3) initial position (height, latitude, longitude) for each profile, and (4) steps

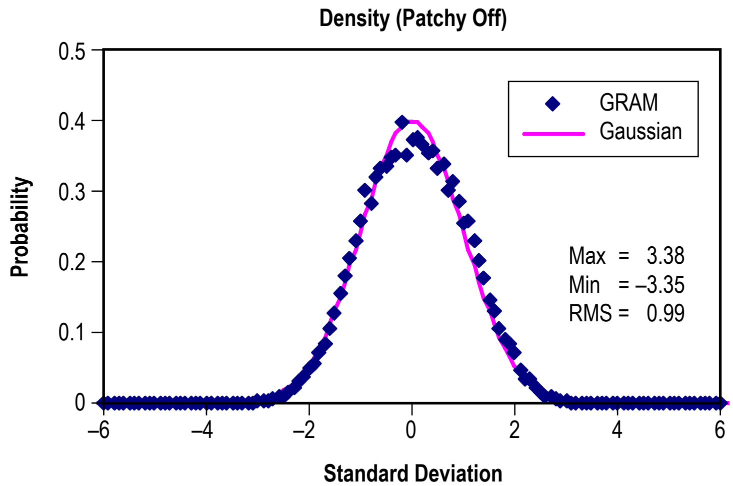

Figure 2. Comparison of GRAM07 density dispersions with a Gaussian distribution.

in time, height, latitude, and longitude along each individual profile. The corrtraj program can be used to simulate a sequence of observed profiles during day-of-launch operations, when conditions can be observed only up to some time before launch, and actual conditions encountered at launch time are correlated with, but not identical to, the last set of observed conditions. Figure 3 shows a plot of an initial profile generated by GRAM07 as well as three profiles that developed at two-hour intervals.

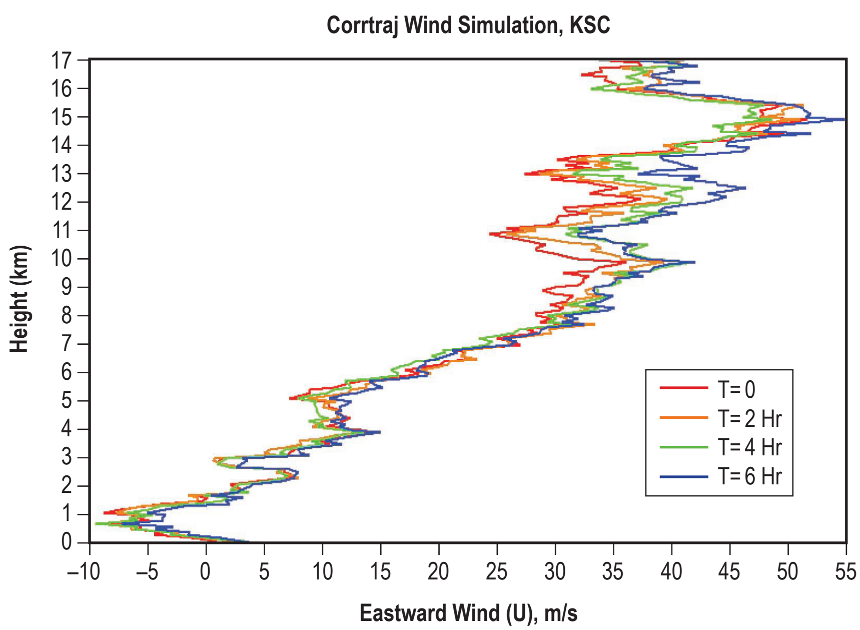

Figure 3. Time evolution of the eastward wind at the Kennedy Space Center (KSC) as computed by the corrtraj program of GRAM07.

(4) Tuning of the length scales to better reproduce wind shears observed at Cape Canaveral, Florida. The original GRAM code was developed in part for Space Shuttle re-entry studies including propellant management. Interest in using GRAM for ascent to examine structural loads led to an evaluation of the wind shears produced by the program. Previous versions tended to underestimate the shears at the higher altitudes. Figure 4 shows a comparison of measured vector wind shear to the GRAM output. Included are measurements from Jimsphere balloons, the Vector Wind Model,[14] rawinsonde balloons, and the Automated Meteorological Profiling System (AMPS). The chart shows the 99th percentile 1,000-meter vector wind change versus altitude. The Jimsphere is a radar-tracked balloon while the AMPS balloon carries a Global Positioning System (GPS) and both are considered more accurate than the rawinsonde that suffers from errors due to low elevation angles during periods of high winds. The GRAM07 agrees within a few meters per second with Jimsphere and AMPS.

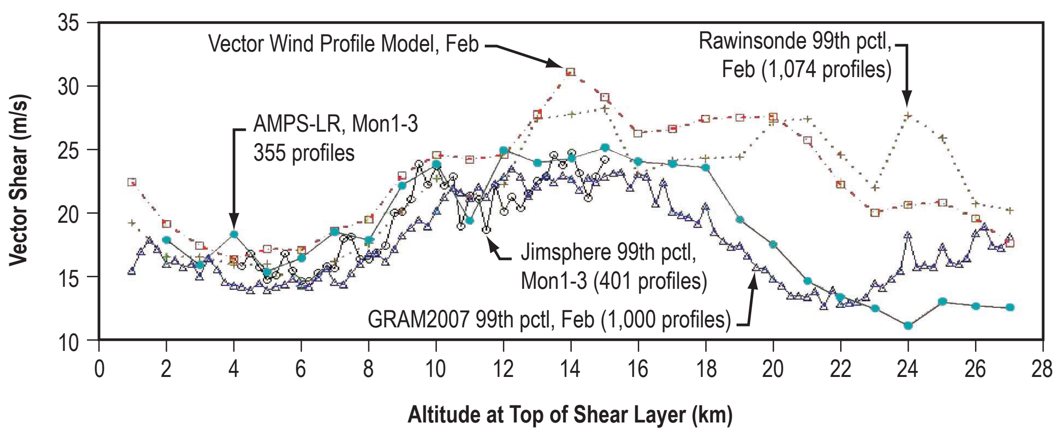

Figure 4. A comparison of GRAM07-generated wind shears with various measurement systems at the KSC.

1.3.2 New Range Reference Atmospheric Model Option

A major feature, new in GRAM-99 and expanded in GRAM07, is the (optional) ability to use data (in the form of vertical profiles) from a set of Range Reference Atmospheres (RRAs), as an alternate to the usual GRAM climatology, at a set of RRA site locations. With this feature it is possible, for example, to simulate a flight profile that takes off from the location of one RRA site (e.g. Edwards Air Force Base (AFB), using the Edwards RRA atmospheric data), to smoothly transition into an atmosphere characterized by the GRAM climatology, then smoothly transition into an atmosphere characterized by a different RRA site (e.g. White Sands, NM), to be used as the landing site in the simulation.

The RRA data consists of information on both monthly means and standard deviations of the various parameters at the RRA site. Under the RRA option, when a given trajectory point is sufficiently close to an RRA site, then the mean RRA data replace the mean values of the conventional GRAM climatology, and the RRA standard deviations replace the conventional GRAM standard deviations in the perturbation model computations. A new feature in GRAM07 is the ability to replace GRAM surface data with surface data from the appropriate RRA site.

A total of 18 sites are provided for 1983 RRA data. A slightly different set of 22 sites are available for 2006 RRA data. The data period-of-record varies from site to site, but is generally late 1950's to late 1970's for the 1983 RRA data, and 1990 to 2002 for the 2006 RRA data. Exceptions for 2006 RRA period-of-record are El Paso (1990–95), Great Falls (1990–94), Taguac (1990–99), China Lake (1948–2000), and White Sands (1949–1993). El Paso RRA data (0–30 km) are augmented with White Sands rocketsonde data from 30–70 km. The White Sands RRA file includes only 0–30 km data. The user can also prepare (in the appropriate format) data for any other desired site for use in the RRA mode. Table 1 lists the 2006 RRA sites available in GRAM07 denoting the station code, year, latitude, longitude, height above sea level, World Meteorological Organization (WMO) station number, and name.

1.3.3 New Auxiliary Profile Option

In addition to RRA options, an "auxiliary profile" feature has been implemented. This allows the user to input a data profile of pressure, density, temperature, and/or winds versus altitude, with the auxiliary profile values used in place of conventional climatology (GUACA/MAP/etc.) values. Setting parameters in the input file controls this option. Parameter *profile* gives the file name containing the profile data values. Parameter *sitenear* is the latitude-longitude (lat-lon) radius (in degrees) within which the weight for the auxiliary profile is 1.0. Parameter *sitelim* is the lat-lon radius (in degrees) beyond which the weight for the auxiliary profile is 0.0. A weighting factor for the profile data, having values between 0 and 1, is applied between radii *sitelim* and *sitenear*. Mean conditions are as given in the *profile* file if the desired point is within a lat-lon radius of *sitenear* from the profile lat-lon at the given altitude; mean conditions are as given by the original GUACA/MAP/etc. data if the desired point is beyond a lat-lon radius of *sitelim* from the lat-lon of the profile at the given altitude. If *sitenear* = 0, then profile data are NOT used. When using an auxiliary profile, the standard deviations used to drive the perturbation model will come from GRAM climatology. The profile weight factor (*profwgt*) for the auxiliary profile also varies between 0 at the first profile altitude level and 1 at the second profile altitude level (and between 1 at the next-to-last profile altitude level and 0 at the last profile altitude level). First and second profile points (and the next-to-last and the last profile points) should therefore be selected widely enough apart in altitude that a smooth transition can occur as *profwgt* changes from 0 to 1 near these profile end points. NOTE: The auxiliary profile option and RRA data option cannot both be invoked simultaneously.

Each line of the auxiliary profile input file consists of: (1) height, in km (height values greater than 6,000 km are interpreted as radius values, in km), (2) latitude, in degrees, (3) longitude, in degrees (east positive), (4) temperature, in K, (5) pressure, in N/m^2, (6) density, in kg/m^3, (7) eastward wind, in m/s, and (8) northward wind, in m/s. Heights are relative to the reference ellipsoid, except that values greater than 6,000 km are interpreted as radius values, rather than altitudes. Latitudes are geocentric. Regular climatological values are used if any values of temperature, pressure, and density data are input as zero in the auxiliary profile. Regular climatological values of wind components are used if BOTH of the wind components are zero in the auxiliary profile file. It is worth noting that the auxiliary profile need not be a simple vertical profile at a fixed lat-lon, but can consist of a data set along a specified trajectory.

Table 1. RRA sites in GRAM07.

Code	Year	GdLat	LonE	Hgt(m)	WMO #	Name
asc	1983	–7.93	–14.42	20.	619020	Ascension Island, Atlantic
bar	1983	22.03	–159.78	5.	911620	Barking Sands, Hawaii
cap	1983	28.47	–80.55	3.	747940	Cape Canaveral, Florida
dug	1983	40.77	–111.97	1,288.	725720	Dugway Proving Ground (Salt Lake City), UT
eaf	1983	34.92	–117.90	705.	723810	Edwards Air Force Base, California
egl	1983	30.48	–86.52	20.	722210	Eglin AFB, Florida
kmr	1983	8.73	167.75	2.	913660	Kwajalein Missile Range, Pacific
ptu	1983	34.12	–119.12	4.	723910	Point Mugu Naval Air Weapons Center, CA
tag	1983	13.55	144.85	111.	912170	Taguac, Guam
vaf	1983	34.75	–120.57	100.	723930	Vandenberg AFB, California
wal	1983	37.85	–75.48	3.	724020	Wallops Island, Virginia
wsm	1983	32.38	–106.48	1,246.	722696	White Sands, New Mexico
fad	1983	64.82	–147.87	135.	702610	Fairbanks, Alaska
nel	1983	36.62	–116.02	1,007.	723870	Nellis AFB, Nevada
shm	1983	52.72	174.12	39.	704140	Shemya, Alaska
thu	1983	76.52	–68.50	59.	042020	Thule, Greenland
wak	1983	19.28	166.65	5.	912450	Wake Island, Pacific
kod	1983	57.75	–152.50	0.	703500	Kodiak, AK (unofficial: Developed by MSFC)
anf	2006	47.62	–52.73	140.	718010	Argentia, Newfoundland (St. Johns Airport)
asc	2006	–7.93	–14.42	79.	619020	Ascension Island, Atlantic
bar	2006	21.98	–159.34	31.	911650	Barking Sands, Hawaii (Lihue)
cap	2006	28.47	–80.55	3.	747940	Cape Canaveral, Florida
chl	2006	35.68	–117.68	665.	746120	China Lake Naval Air Weapons Center, CA
dug	2006	40.77	–111.97	1,288.	725720	Dugway Proving Ground (Salt Lake City), UT
eaf	2006	34.92	–117.90	724.	723810	Edwards Air Force Base, California
egl	2006	30.48	–86.52	20.	722210	Eglin AFB, Florida
elp	2006	31.81	–106.38	1,199.	722700	El Paso, Texas
fad	2006	64.80	–147.88	135.	702610	Fairbanks, Alaska
fha	2006	32.12	–110.93	787.	722740	Ft. Huachuca Elec Prvng Grnd (Tucson), AZ
gtf	2006	47.47	–111.38	1,118.	727750	Great Falls, MT
kmr	2006	8.73	167.75	2.	913660	Kwajalein Missile Range, Pacific
ncf	2006	43.87	4.40	62.	076450	Nimes–Courbessac, France (STS TAL Site)
nel	2006	36.62	–116.02	1,007.	723870	Nellis AFB, Nevada (Mercury)
ptu	2006	34.12	–119.12	2.	723910	Point Mugu Naval Air Weapons Center, CA
rrd	2006	18.43	–66.00	3.	785260	Roosevelt Roads (San Juan), Puerto Rico
tag	2006	13.55	144.85	78.	912170	Taguac, Guam (Anderson AFB)
vaf	2006	34.75	–120.57	121.	723930	Vandenberg AFB, California
wal	2006	37.85	–75.48	13.	724020	Wallops Island, Virginia (NASA)
wsm	2006	32.38	–106.48	1,207.	722690	White Sands Missile Range, New Mexico
ysd	2006	32.87	–117.14	134.	722930	Yuma Proving Ground, AZ (San Diego, CA)

1.3.4 New Thermosphere Model Options

The GRAM07 now allows the user to select one of three thermosphere models for use above 90 km: the new Marshall Engineering Thermosphere (MET2007), the Naval Research Labs Mass Spectrometer, Incoherent Scatter Radar Extended Model thermosphere (NRL MSIS E-00) with the associated Harmonic Wind Model (HWM-93), or the Jacchia-Bowman 2006 thermosphere model (JB2006). The default model is the MET2007[15–18] that has been updated to include:

(1) A correction of number density and molecular weight, according to discussion in Justus et al.[19]

(2) A change from spherical-Earth approximation to latitude-dependent surface gravity and effective Earth radius.

(3) A change from time resolution only to the nearest integer minute to (real) seconds time resolution.

(4) A correction of small discontinuities in the semiannual variation term by converting day-of-year to real instead of integer, and treating each year as having either 365 or 366 days (as appropriate), rather than all years being treated as a length of 365.2422 days.

(5) An additional output from MET07_TME subroutine of modified Julian day, right ascension of sun, and right ascension at local lat-lon (used for input to new JB2006 thermosphere model).

Information on the NRL and JB2006 models can be found in section 2.1.

1.3.5 New Coordinate System Changes and Revised Earth Reference Ellipsoid

Equatorial and polar Earth radii for the "sea-level" reference ellipsoid have been updated to World Geodetic System (WGS 84) values. Previous (Earth GRAM-99) radius values were from International Astronomical Union (IAU) 76. The WGS 84 values are used by the GPS navigation system. These are also equivalent (to 10 significant figures) to the Geodetic Reference System (GRS 80) values. Other recent values that could be used include the International Earth Rotation and Reference System (IERS 1989) values. Earth radius values are set by parameter values in one of the GRAM07 subroutines. Input values of altitude greater than 6,000 km are treated as geocentric radius values, rather than heights. Both radius and height are now given in the output file. Although all input latitudes are geocentric, GRAM07 now gives both geocentric and geodetic values on the output file. A new subroutine has also been added which computes horizontal distance from great-circle distance between two input lat-lon positions. This subroutine is used to calculate lat-lon "radius" of current position from RRA site locations and to compute horizontal step size in the perturbation model.

1.3.6 New NAMELIST Format Input

The GRAM07 has seven new input parameters that are provided through the NAMELIST input file:

profile: path name for auxiliary profile data (if auxiliary profile option is selected)
iyrrra: for user selection of either 1983 or 2006 RRA input (if the RRA option is selected)
itherm: for user selection of either MET (Jacchia), MSIS, or JB2006 thermosphere model
s10: extreme ultraviolet (EUV) index (26-34 nm) scaled to F10 units (0.0 g s10 = f10), used by the JB2006 model
s10b: EUV 81-day center-averaged index (0.0 g s10b = f10b), used by the JB2006 model
xm10: double-ionized magnesium (MG2) index scaled to F10 units (0.0 g xm10 = f10), used by the JB2006 model
xm10b: MG2 81-day center-averaged index (0.0 g xm10b = f10b), used by the JB2006 model

1.3.8 New Information on Standard Formatted Output

A reference NAMELIST input file (NameRef.txt) and resulting standard formatted output file (OutputRef.txt) "special-formatted" output file (SpecialRef.txt), and species output file (SpeciesRef.txt) are supplied with the GRAM07 software. New information appearing on the standard formatted output file includes:

(1) Both height and geocentric radius values

(2) Both geocentric and geodetic latitude (input values are geocentric)

(3) Indication about which version of RRA data are used (if the RRA option is in effect)

(4) Name of auxiliary profile input data file (if auxiliary profile option is being used).

1.4 Summary of Global Reference Atmospheric Model 07 Characteristics

1.4.1 The Output Is Based on Atmospheric Measurements

The lowest 27 km of the model utilizes measurements from the GUACA or the RRA database that have been quality checked. Although newer databases may exist, the GUACA data set has global coverage, contains pressure, temperature, and winds, and also contains both means and standard deviations. The middle atmosphere of the model is based on the available (though limited) data from rocket and remote sensing programs. Finally, the upper atmosphere uses one of three thermospheric models that have been guided by data from satellite observations.

1.4.2 The Model Can Be Driven by External Data

If the user has atmospheric data that is believed to be more appropriate for their application than that contained within GRAM07, the data can be easily ingested into the model using the auxiliary profile option. For example, the GUACA data set and the RRAs contain monthly means that do not represent a particular time of day. If a user is interested in early morning conditions at a particular site, the monthly mean may not be representative of that environment. Alternatively, a site-specific, time-specific data set from local observations could be compiled and utilized. Furthermore, it is worth mentioning that the auxiliary profile need not be a vertical profile, but could also be data-dependent on lat-lon as well as height. Alternatively, the user could also provide model data by adding an RRA site to the database as described in section 2.8. The advantage of this technique is that new data on standard deviations could be utilized.

1.4.3 Monte Carlo Runs Reproduce the Observed Means and Standard Deviations

In GRAM07, when a large number of Monte Carlo dispersions are generated at any location, the mean and standard deviation of these data will match those of the observations. This is important in order for the model to be statistically equivalent to available measurements.

1.4.4 The Total Dispersions Are Approximately Gaussian-Distributed

The sum of large- and small-scale dispersions are approximately Gaussian-distributed, with the exception being pressure where most of the variance is due to the large-scale since small-scale pressure variations equilibrate quickly. Because the large-scale is modeled with a cosine wave, the probability distribution is influenced by that function to a larger degree. New introduction of randomly varying amplitudes for large-scale wave perturbations makes the total dispersions more Gaussian. Therefore, various exceedances can be expected with a more normal frequency.

1.4.5 The Small-Scale Dispersions Have a Dryden Power Spectrum

Since the small-scale dispersions are modeled with a one-step Markov technique having a correlation coefficient that decreases exponentially with distance (and time), the energy spectrum is inversely proportional to both the square of the wave number (spatial frequency) and the square of the time frequency. Thus, most of the observed variance occurs over large length (and time) scales.

1.4.6 The Computed Wind Shears Are Consistent with Those Observed at Kennedy Space Center

Structure function analysis of wind shears observed at KSC from balloon and tower data resulted in improvements in the perturbation model. For a comparison of the model to measured data, see figure 4.

2. TECHNICAL DESCRIPTION OF THE MODEL

2.1 The Upper Atmosphere Section

The GRAM07 has the option of three different thermosphere models for use above 90 km. The newly-released MET-07[18] constitutes the default upper atmosphere model. The equinox of epoch J2000 is used to compute solar positions. Slight changes were made in the parameters of the perturbation model input parameters used at 200 km and above. These changes make the density perturbations from GRAM07 more consistent with those determined by Hickey.[20,21] In the original GRAM climatology, random perturbation standard deviations in density at 200 km and above were latitude-invariant with a magnitude of 5.2 percent. New density perturbation magnitudes at 200 km and above (code RD data in the atmosdat file) vary from 3.0 percent at the equator to 8.0 percent at the poles. The large-scale perturbation fraction, f_L, in section 4.2.4 (code PT data in the atmosdat file) was also changed to a value of 0.131 to reflect a larger fraction of the total density variance in large-scale perturbations. Changing the applicable values of f_L and density standard deviation has a corresponding effect on the magnitudes of pressure and temperature perturbations.[6] As at other altitudes, large-scale perturbations in the GRAM07 MET region are computed as a cosine wave perturbation rather than the one-step Markov large-scale model in GRAM-95.

The Jacchia model[22] in MET-07 for the thermosphere and exosphere was originally implemented to compute atmospheric density and temperature at satellite altitudes. It represents total atmospheric density by summing the densities of six, separately modeled, atmospheric constituents (N_2, O_2, O, Ar, He, and H). The Jacchia model accounts for temperature and density variations due to solar and geomagnetic activity, diurnal, seasonal, and lat-lon variations throughout the height range above 90 km. The Jacchia model assumes a uniformly-mixed composition below 105 km, with diffusive equilibrium among the constituents above 105 km. Fixed (time-independent) boundary values for temperature and density are assumed at 90 km. Alterations, described in Justus et al.,[2] were made to allow atmospheric pressure to be computed from the density and temperature. Geostrophic wind components, modified by the effects of molecular viscosity[5] are evaluated in the Jacchia section by using the Jacchia model to estimate horizontal pressure gradients. In previous GRAM versions, the NASA MET model[16,17] was implemented to characterize the mean atmosphere above 120 km. GRAM07 now uses the newly-released 2007 version of MET.[18] Between 90 and 120 km, a fairing process (described in section 2.5) ensures smooth transition between the MET model values and the middle atmosphere data.

As an alternative to MET, an option is now provided to use the 2000 version NRL MSIS extended model, NRLMSISE-00, for thermospheric conditions. If this option is selected, thermospheric winds are evaluated using the NRL 1993 HWM-93. If the MET option is selected, winds are computed from a geostrophic wind model, with modifications for thermospheric effects of molecular viscosity. This wind model has been used in GRAM since the 1990 version.[13]

Information on the MSIS and HWM models is available at the following web sites:

<http://www.nrl.navy.mil/content.php?P=03REVIEW105>
<http://uap-www.nrl.navy.mil/models_web/msis/msis_home.htm>
<http://modelweb.gsfc.nasa.gov/atmos/nrlmsise00.html>
<http://www.answers.com/topic/nrlmsise-00>
<http://fact-archive.com/encyclopedia/NRLMSISE-00>
<http://nssdc.gsfc.nasa.gov/space/model/models_home.html#atmo>
<http://uap-www.nrl.navy.mil/models_web/homepage.htm>

Minor corrections in MSIS and HWM have been made. Therefore, MSIS/HWM output from GRAM07 will not agree totally with output from the original NRLMSISE-00 version.

Another option is the Jacchia-Bowman 2006 (JB2006) model developed using the Committee On Space Research (COSPAR) International Atmosphere 72 (Jacchia 71) model as the basis for the diffusion equations. New solar indices have been used for the solar irradiances in the extreme and far ultraviolet wavelengths. New exospheric temperature and semiannual density equations were created to represent the major thermospheric density variations. Temperature correction equations were also developed for diurnal and latitudinal effects, and finally density correction factors have been included for model corrections required at high altitudes (1,500–4,000 km). This model has been validated through comparisons of accurate daily density drag data previously computed for numerous satellites. For the 400-km altitude the standard deviation of 16 percent for the Jacchia 71 model has been reduced to 10 percent in the JB2006 model during periods of low geomagnetic storm activity. References to developmental papers for JB2006 are given in the code (JB2006_E07.f) and at the JB2006 web site:

<http://sol.spacenvironment.net/~JB2006/>

This site has links to new solar indices required by JB2006 (s10 and xm10), JB2006 source code, publications, contacts, figures, and the Space Environment Technologies Space Weather site. The starting point for the GRAM implementation of JB2006 is REV-A October, 2006. The changes were mostly cosmetic and were to make the code more transportable among various compilers. If JB2006 is selected for calculation of thermospheric density and temperature, winds are computed with the HWM 93 that is used in conjunction with the MSIS model.

A two-scale perturbation model is used in GRAM07. Small-scale perturbations are computed by a one-step Markov process (a first order autoregressive approach, equivalent to the first order autoregressive model of Hickey).[20] A wave model for treating large-scale perturbations was introduced in GRAM-99. This model uses a cosine wave, with both horizontal and vertical wavelengths. For use in Monte Carlo simulations, a degree of randomness is introduced into the large-scale wave model by randomly selecting the amplitude and phase of the cosine wave (under control of the same random number seed values as used for the small-scale perturbations). Parameters for the small-scale perturbation model in GRAM-99 and GRAM07 were recalculated to produce good agreement with data given in table 2 of Hickey.[20] The one-step correlation over 15 seconds of movement for the Atmospheric Explorer (AE) satellites is equivalent to an average value of 0.846

(with a standard deviation of 0.040). The length scales used in the perturbation model of GRAM-99 and GRAM07 yield a correlation value of 0.870 over the distance which the AE satellite moves in 15 seconds, well within the range of variability of the correlation data from Hickey. See further discussion of the thermospheric perturbation model in section 3.3 of the GRAM-99 report.[7] The large-scale (wave) and small-scale (Markov) model for perturbations in GRAM07 is used at all altitudes, not just in the MET or MSIS model altitude range.

2.2 The Middle Atmosphere Section

The MAP data in GRAM characterizes the monthly mean middle atmosphere (20 to 120 km) by two gridded data sets, one representing the zonal mean atmospheric values (gridded by height and latitude) and the other the monthly-mean stationary wave patterns (i.e. stationary perturbations about the monthly mean, gridded by height, latitude, and longitude). The zonal mean data set was merged from six separate data sets covering the 20 to 120 km altitude range. The zonal monthly mean data set (pressure, density, temperature, and mean eastward wind component) is gridded in 10° latitude and 5-km height increments (–80 to +80° and 20 to 120 km). Zonal mean values at ±90° are computed by an across-the-pole interpolation scheme discussed in section 2.5. Zonal mean values between the gridded data set values are interpolated vertically by hydrostatic and perfect gas law assumptions and horizontally by two-dimensional (lat-lon) interpolation methods.

The stationary perturbation data set (standing wave perturbations in pressure, density, temperature, and eastward and northward wind components) was merged from three sources of data on planetary-scale standing wave patterns.[5] This data set is gridded in 10° latitude increments (–80 to +80°), 20° longitude increments (180°, 160°W, 140°W,... 140°E, 160°E), and 5-km height intervals (20 to 90 km). Stationary perturbations are identically zero at the poles. Stationary perturbation values are linearly interpolated in the vertical dimension and horizontally by two-dimensional (lat-lon) interpolation methods.

2.3 The Global Upper Air Climatic Atlas or the Global Gridded Upper Air Statistics Section

The GUACA or GGUAS data sets contain monthly means and standard deviations in temperature, density, dewpoint temperature, sea level pressure, geopotential height, and eastward and northward wind components. The data are gridded globally at 2.5 by 2.5-degree resolution in 144 longitudes (0°, 2.5°E, ... 2.5°W) and 73 latitudes (–90°, -87.5°, ... +90°) at the surface and 14 constant pressure levels from 1,000 to 10 mb (app. A and B).

For grid points where the surface is higher than one or more of the pressure levels, the data at these levels are coded as missing. In order to estimate data at all altitudes from sea level (0 km) and above (e.g. for a "valley" site at a lower altitude than the surface at the adjacent 2.5° grid points), GRAM fills in all missing data from sea level to the surface at each grid point. This is done by first using the hydrostatic relationship to compute the surface altitude at the grid point from sea level pressure and the geopotential height of the lowest altitude grid point value. Next, the hydrostatic assumption is used to fill in the thermodynamic values between sea level and the surface by assuming a constant temperature over this layer (the standard assumption in computing sea level pressure from measured, station-level pressure).

Array sizes in GRAM07 are set large enough to read in the full global GUACA data set at one time (for a given month). This eliminates the characteristic in GRAM versions prior to 1995 whereby only a limited-area lat-lon grid of lower altitude data was loaded at one time. This feature improves GRAM performance for such applications as trajectory calculations since (after the initial data setup process) there is no need for processing delays while a new low-altitude grid of data is read in.

All "fixing" of the GUACA data is done globally as part of the GUACA array setup and initialization. These processes include the filling in of values between sea level and the surface, inserting any missing data values, and correcting any discrepancies in the relationship among the standard deviations in pressure, density, and temperature. Density values at 70 mb for the period-of-record (1980 to 1991) data set require correction (app. A). Missing values (especially pole winds above 70 mb, for some years) are input. Dewpoint temperatures above the 300-mb level are filled in by extrapolation using a decreasing relative humidity profile. These GUACA-extrapolated moisture values are used only between 300 and 100 mb where they are faired with NASA (LaRC) water vapor values (section 2.5).

The perfect gas law implies certain constraints on the relationship that must exist between the standard deviations and mean values of pressure, density, and temperature. The GUACA database values of standard deviations are subjected to a test for this constraint and adjusted (so density-temperature correlation does not exceed 0.999 in magnitude) for all cases that produce a violation. Standard deviations in pressure (above the surface) are computed from the standard deviations in geopotential height by a hydrostatic assumption.

2.4 Water Vapor and Other Atmospheric Species Concentrations

Water vapor and other atmospheric species concentrations were introduced in GRAM-95, with values above 90 km from the MET model and via a new species concentration database discussed in section 4.3 of Justus et al.[6] Water vapor output from GRAM07 includes both monthly means and standard deviations. Within the GUACA height range, the water vapor values vary with month, height, latitude, and longitude above that range, the values vary with month, height, and latitude.

Means and standard deviations in water vapor are represented in the form of vapor pressure (N/m^2), vapor density (kg/m^3), dewpoint temperature (K), and relative humidity (%). Mean water vapor values in the form of volume concentration (parts per million by volume (ppmv)) and number density (molecules/m^3) are also output. Conversions from the form in the input data (dewpoint temperature for the GUACA data and volume concentration for the other water vapor data sources) are performed by various subroutines. Only monthly mean concentration values are output for the species, other than water vapor, and in the form of volume concentration and number density.

Interpolation of the GUACA (or GGUAS) dewpoint temperature for altitudes between the input pressure levels and for lat-lon between the input grid points is handled the same as the other GUACA (or GGUAS) variables. Height and latitude interpolation between input height-latitude grid points for water vapor above 27 km, and for the other species, is done by an adaptation of the two-dimensional interpolation discussed in section 2.5 (to do height-latitude interpolation rather than lat-lon interpolation).

Species concentrations $c(t)$ are assumed to change with year, t, according to the relation

$$c(t) = c(t_0)(1 + r_t)^{t - t_0} \quad , \tag{1}$$

where t_0 is 1976 for the AFGL data and 1981 for the MAP concentration data and r_t is 0.005 for CO_2, 0.009 for CH_4, 0.007 for CO, and 0.003 for N_2O. For ozone, r_t varies linearly from 0.003 at the surface to 0 at 15 km, linearly from 0 at 30 km to –0.005 at 40 km, and again linearly from –0.005 to 0 at 120 km. The rate of change, r_t, for water vapor and the other constituents is assumed to be zero.

2.5 Interpolation and Fairing Techniques

2.5.1 Vertical Interpolation

Pressure, $p(z)$, temperature, $T(z)$ and density, $\rho(z)$, obey the perfect gas law

$$p = \rho RT \quad , \tag{2}$$

where R is the gas constant. They also agree very closely with the hydrostatic assumption

$$dp / dz = -\rho g \quad , \tag{3}$$

where g is the acceleration of gravity. If there are grid-point pressure values, p_1 and p_2, and temperature values, T_1 and T_2, at heights, z_1 and z_2, then vertical interpolation to any height z (between z_1 and z_2) is done by assuming a linear temperature variation

$$T(z) = T_1 + \gamma(z - z_1) \quad , \tag{4}$$

where γ is the temperature gradient

$$\gamma = (T_2 - T_1) / (z_2 - z_1) \quad . \tag{5}$$

The hydrostatic relation, with a constant temperature gradient implies a power-law variation with pressure. So pressure, $p(z)$, may be computed by

$$p(z) = p_1 [T(z) / T_1]^a \quad , \tag{6}$$

where the exponent, a, is given by

$$a = \log(p_2 / p_1) / \log(T_1 / T_2) \quad . \tag{7}$$

The density, $\rho(z)$, is found by solving the perfect gas law relation equation (2).

In the GUACA height range, this vertical interpolation is complicated by the fact that the moisture varies with height and the gas constant for moist air depends on the moisture concentration. For the GUACA data, a variant of equation (6) uses an interpolated gas constant, R, and the fact that the exponent, a, is given by $a = g/(R\gamma)$.

The form of vertical interpolation given by equation (6) is used to fill in mean values of pressure, density, and temperature between the input pressure levels of the GUACA data (with z the geopotential height) and the zonal mean values between the input height grids of the MAP database. Other variables that do not obey perfect gas law relationships (e.g. wind components, dewpoint temperature, and all standard deviations) are interpolated linearly in the vertical.

2.5.2 Two-Dimensional Interpolation

Let V be a variable that is available on a two-dimensional grid array (x and y) and consider the grid point values $V_{11} = V(x_1, y_1)$, $V_{12} = V(x_1, y_2)$, and $V_{21} = V(x_2, y_1)$ and $V_{22} = V(x_2, y_2)$. Then any value $V(x,y)$ (for x between x_1 and x_2 and y between y_1 and y_2) may be found by the interpolation scheme

$$V(x,y) = \alpha'\beta' V_{11} + \alpha'\beta V_{12} + \alpha\beta' V_{21} + \alpha\beta V_{22} \quad , \tag{8}$$

where $\alpha = (x - x_1)/(x_2 - x_1)$, $\alpha' = 1 - \alpha$, $\beta = (y - y_1)/(y_2 - y_1)$, and $\beta' = 1 - \beta$. This interpolation relation is mathematically equivalent to that used (for lat-lon interpolation) in earlier GRAM versions but is expressed here in a more symmetric notation.

Equation (8) is used to interpolate between lat-lon grid points (x = longitude, y = latitude) for the GUACA grids and the stationary perturbation grids of the MAP data. For variables dependent on a height-latitude (or a pressure-latitude) grid (such as the species concentration data), then equation (8) is used with y = latitude and x = height (or x = log pressure). The variables actually interpolated for concentration data are the logarithms of the concentration values.

2.5.3 Interpolation Across the Poles

Several GRAM databases that are height-latitude dependent lack values at or near the poles. These are filled in by an interpolation procedure that assumes a parabolic variation (across both sides of the pole) that fits the last and next-to-last available latitude. The results are a weighted average of these last and next-to-last latitude values. For example, if values of a parameter are available at ±70° and ±80°, but not at ±90°, then the missing polar values are supplied by

$$y_{+90} = (4y_{\pm 80} - y_{\pm 70})/3 \quad . \tag{9}$$

If values are available at ±60 and ±70° but not at ±80 or ±90° then the missing values are supplied by

$$y_{\pm 90} = \left(9 y_{\pm 70} - 4 y_{\pm 60}\right) / 5 \tag{10}$$

and

$$y_{\pm 80} = \left(8 y_{\pm 70} - 3 y_{\pm 60}\right) / 5 \ . \tag{11}$$

For the species concentration data, this interpolation is done on the logarithm of the concentration values.

2.5.4 Fairing Between Two Data Sets

If there are two data sets, $A(z)$ and $B(z)$, that overlap throughout the height range from z_1 to z_2 (with A valid below z_2 and B valid above z_1 and $z_2 > z_1$), then a fairing process

$$C(z) = f(z) A(z) + \left[1 - f(z)\right] B(z) \tag{12}$$

ensures a smooth transition for the faired variable, C, across the height interval from z_1 to z_2 if $f\left(z_1\right) = 1$ and $f\left(z_2\right) = 0$. Thus, $A(z)$ is used below z_1, $B(z)$ above z_2, and the faired variable, $C(z)$, varies smoothly between $A(z)$ and $B(z)$ as z varies from z_1 to z_2. A linear form is used for f

$$f(z) = \left(z_2 - z\right) / \left(z_2 - z_1\right) \tag{13}$$

or, with variables for which continuity of vertical derivatives is important, f is taken as

$$f(z) = \cos^2\left[(\pi / 2)\left(z - z_1\right) / \left(z_2 - z_1\right)\right] \ . \tag{14}$$

Equation 14 is used in fairing between the GUACA and MAP data between 20 and 27 km, between the thermosphere model and MAP data between 90 and 120 km, and the H number density in the MET model between 440 and 500 km. For fairing the species concentration data, equation (13) is used with the logarithm of the species concentration as the variable to fair.

2.5.5 Seasonal and Monthly Interpolation

Some of the species concentration databases do not contain monthly data. For example, the AFGL concentrations are seasonal averages (summer and winter); the LaRC water vapor data have four seasonal averages, and the MAP water vapor data have only certain months of the year (November through May). The initialization routines in GRAM use an annual harmonic temporal variation model to estimate the concentration data for the specific month to be simulated. For the AFGL data this is accomplished by applying pre-computed weights to obtain a weighted average of the summer and winter values used to estimate the value for the specific month. For the LaRC water vapor data a weighted average of the two adjacent seasonal values is used to estimate the monthly value (i.e. Mar–Apr–May and Jun–Jul–Aug values are used to estimate the monthly values for May and June with different weights applied for each month). For the MAP water vapor data a combination of annual harmonic Fourier fit and 6-month displacement from northern to southern hemisphere (and vice-versa) is used at initialization to establish the global values for each month from the monthly values of November through May in the database.

2.6 The Perturbation Model

2.6.1 Small-Scale Perturbation Model

GRAM07 uses a simple, first-order, autoregressive model to compute a perturbation at each new position from necessary correlation between these successive perturbation values, the model accounts for the effects of variation in the mean values and the standard deviation from one position to another. Consider a normalized variate $\mu(\mathbf{x})$ (i.e. μ is the deviation of the value from the mean value, divided by the standard deviation, all at the vector position $\mathbf{x}$). The perturbation model computes $\mu(\mathbf{x}')$ at the next trajectory position $\mathbf{x}'$

$$\mu(\mathbf{x}') = r\mu(\mathbf{x}) + \left(1 - r^2\right)^{1/2} q(\mathbf{x}) \quad , \tag{15}$$

where q is a Gaussian-distributed random number with a mean of 0 and standard deviation of 1, and r is the auto-correlation between the successive values of the normalized variate, i.e.

$$r = < \mu(\mathbf{x}')\mu(\mathbf{x}) > \quad , \tag{16}$$

where the angle brackets denote an average. The auto-correlation value, r, is obviously a function of the vector displacement $\delta\mathbf{x} = \mathbf{x}' - \mathbf{x}$.

Consider two normalized variates, $\mu(\mathbf{x})$ and $v(\mathbf{x})$, (each relative to its own mean value and each normalized by its own standard deviation), that have a cross-correlation r_c between them (i.e. $r_c = < \mu(\mathbf{x})v(\mathbf{x}) >$). Variate $v(\mathbf{x}')$ at the new position is computed from $v(\mathbf{x})$ and $\mu(\mathbf{x}')$ by

$$v(\mathbf{x}') = r_v v(\mathbf{x}) + r_\mu \mu(\mathbf{x}') + r_q q(\mathbf{x}) \quad , \tag{17}$$

where the coefficients are given by

$$r_v = r\left(1 - r_c^2\right) / \left[1 - (rr_c)^2\right] \; , \tag{18}$$

$$r_\mu = r_c\left(1 - r^2\right) / \left[1 - (rr_c)^2\right] \; , \tag{19}$$

and

$$r_q = \left(1 - r_v^2 - r_\mu^2 - 2r_v r_\mu r_c r\right)^{1/2} \quad . \tag{20}$$

Auto-correlation values, r, are computed by assuming an exponential correlation function

$$r(\delta\mathbf{x}) = \exp\left(-\delta h / L_h\right)\exp\left(-\delta z / L_z\right)\exp\left(-\delta t / \tau\right) \tag{21}$$

where δh and δz are the magnitudes of the horizontal and vertical components of $\boldsymbol{\delta x} = \mathbf{x}' - \mathbf{x}$ and L_h and L_z are horizontal and vertical scale parameters that are functions of height and latitude only. Time correlation (even in the special case when the users selects $\delta h = 0$ and $\delta z = 0$) is accounted for by the third exponential term in equation 21 where τ is a time scale that varies with height and δt is the magnitude of the time step between data points.

GRAM07 computes the density and vertical velocity perturbations using only autocorrelation (using a form of equation 16 with the correlation coefficient from eq. (21)). Pressure perturbations are computed with cross correlation to density (using a form of eq. (17), correlation coefficients from eq. (18–21)), and a Buell formulation[23,24] for the pressure-density correlation). The temperature perturbation is computed from a first order version of the ideal gas law and Buell relations. The horizontal wind perturbations are also cross-correlated with the wind-density correlation given in the "atmosdat" data file (see section 4.2). For additional discussion of the perturbation model, see the 2.6 of this TM and sections 2.6 and 2.7 of Justus et al.[6]

Generation of GRAM perturbations starts with observed (climatological) values of total standard deviation of observations about the monthly mean. Total variance (square of the standard deviation) is partitioned into variance contributed by two perturbation components: (1) a large-scale, wave-like perturbation, and (2) a small-scale stochastic (random) perturbation. In order to improve representation of wind shears (discussed in section 1.3.1), updates (changes and additions) to the GRAM07 perturbation code were as follows:

(1) Updates to make the partitioning of the total variance of the eastward wind component into large-scale and small-scale parts the same as the partitioning used for the northward wind component.

(2) Incorporation of a height-dependent factor that affects the correlation scales of the small-scale perturbations throughout the 0-30 km altitude interval (but not above).

(3) Increasing the vertical wavelength of the wave-like, large-scale perturbations.

(4) Addition of explicit time-dependence of wave phase for the large-scale perturbations of estimates of initial perturbation standard deviations for pressure and temperature.

(5) Changes to limit magnitudes of pressure perturbation standard deviations, and to improve the fidelity of estimates of initial perturbation standard deviations for pressure and temperature.

As noted above, none of these updates affect the mean values from GRAM, just the values of the perturbations about the mean, and the Monte Carlo-computed standard deviations for the pressure and temperature perturbation. None of these changes affect standard deviations for density or winds. However, wind gradients (shears, or changes in wind over a specified height or spatial increment) would be affected by these updates. Vertical shears from the large-scale, wave-like perturbations in GRAM are proportional to A/λ, where A is the local wave amplitude and λ is the local vertical wavelength. Vertical shears from the small-scale, stochastic perturbations in GRAM are proportional to σ/L, where σ is the local standard deviation of the small-scale perturbations, and L is the local vertical correlation scale for the small-scale perturbations. An increase in vertical wavelength λ (item 3, above) therefore yields smaller vertical shears from the large-scale, wave-like perturbations. The new height-dependent factor on vertical and horizontal correlation scales (item 2, above) increases L below about 15 km, while decreasing L above about 15 km. This effect decreases (increases) small-scale shears at heights below (above) 15 km, while leaving small-scale shears above 30 km unchanged. The addition of time dependence for the large-scale perturbations (item 4, above) allows GRAM to simulate synoptic-scale variations in time as well as space.

2.6.2 Patchy Severe Turbulence

In order to approximate intermittency ("patchiness") in the perturbations, a variable scale model was introduced in GRAM-95[6] and also used in GRAM07. The GRAM database ("atmosdat" data file, described in section 4.2) includes (for both horizontal and vertical scales) values for average scale size (L_{avg}), minimum scale size (L_{min}), and standard deviation of the variable scale size (σ_L). Periods of "severe" perturbations are characterized as having a scale size of L_{min}.

In the revised perturbation model "non-severe" (i.e. light-to-moderate) perturbations are characterized as having a scale size of L_{max}, such that

$$L_{avg} = P_{sev} L_{\min} + \left(1 - P_{sev}\right) L_{\max} \quad , \tag{22}$$

where P_{sev} is the probability of encountering severe perturbations, given by

$$P_{sev} = P_{tail}\left(\left(L_{avg} - L_{\min}\right) / \sigma_L\right) \quad , \tag{23}$$

where P_{tail} is the tail probability of a Gaussian distribution. From equation (22) the scale for non-severe perturbations is given by

$$L_{max} = \left(L_{avg} - P_{sev} L_{min}\right) / \left(1 - P_{sev}\right) \quad . \tag{24}$$

Furthermore, the variance of the severe perturbations is assumed to be $f_{sev}\,\sigma^2$, and the variance of the non-severe perturbations is assumed to be $f_{non}\,\sigma^2$, where σ^2 is the total variance of the small-scale perturbations (σ, the standard deviation of the small-scale perturbations is also given in the atmosdat file data). Considering the probability of occurrence, σ^2 is given by

$$\sigma^2 = P_{sev} f_{sev} \sigma^2 + \left(1 - P_{sev}\right) f_{non} \sigma^2 \tag{25}$$

From standard deviation data in Justus et al.,[13] the factor f_{sev} is approximated as varying with height, z, having values ranging from 6 at $z = 0$, to 12 at $z = 10$ km back to 6 at $z = 16$ km (and higher). With f_{sev} thus specified, f_{non} is calculated from equation (25) by

$$f_{non} = \left(1 - f_{sev} P_{sev}\right) / \left(1 - P_{sev}\right) \quad . \tag{26}$$

As GRAM07 simulates perturbations along a given trajectory, it uses a random number generator to decide when (with probability P_{sev}) the perturbations are in the "severe" category. During this time, the variance is adjusted from its non-severe magnitude ($f_{non}\,\sigma^2$) to its severe magnitude ($f_{sev}\,\sigma^2$). Patchy severe turbulence is applied only to the small-scale perturbations and not the large-scale, and is enabled only when the parameter *patchy* (in the input file) has a nonzero value.

2.6.3 The Large Scale Perturbation Model

As indicated in section 1.3.1, the largest magnitude perturbation that can occur with a wave perturbation of amplitude A is 1.4 times A. This can lead to total (large-scale plus small-scale) perturbations that are distinctly non-Gaussian in their distribution "tails" (i.e. values of 2–3 sigma may be under-represented). To avoid this situation, a new feature was implemented to randomly select amplitudes for the large-scale perturbations. For a set of Monte Carlo runs, a given amplitude is selected from the range between approximately 0.5 to 1.5 times the nominal amplitude value. The average of a set of Monte Carlo perturbation values will still closely reproduce the expected mean and standard deviation, but the randomly-changing large-scale amplitudes, from one member to another in the Monte Carlo set, will yield a perturbation distribution that is much more nearly Gaussian than previously (see fig. 2).

2.7 Optional User-Selected Initial Perturbations

As in the previous version of GRAM, GRAM07 allows, as a user-controlled option, the input of user-selected initial perturbation values. This option is controlled by the input parameter, *initpert* (with *initpert* = 0, the default value, meaning that GRAM-selected random initial values are used and *initpert* = 1 requiring user-selected values for the initial perturbations).

An example application for user-selected initial perturbations is the following: Suppose a measured profile (e.g. a day-of-launch atmospheric sounding) is to be used as an actual (perturbed) profile to the highest measured altitude and a GRAM07 perturbed profile (or profiles) is desired for higher altitudes. Actual atmospheric values from a measured profile are used to compute perturbed values to initialize GRAM07 (by methods discussed more fully in the next paragraph). With these initial perturbation values GRAM07 perturbed profile(s) for the higher altitude region have complete continuity with the measured profile from the lower altitude region.

Suppose, in this example, the measured profile extends to an altitude of 25 km. Also suppose the measured values at 25 km are density = 0.044 kg/m^3 and eastward wind = 14 m/s (along with other measured values). To use the user-selected initial perturbation option, a GRAM run is performed, starting at 25 km in this example with the same latitude, longitude, and month as the measured profile. Suppose this GRAM run gives a mean density of 0.040 kg/m**3 and mean eastward wind of 20 m/s. The values of user-selected initial density and eastward wind perturbations to use in subsequent GRAM runs are:

initial density perturbation (%) = 100*(measured density – GRAM mean)/GRAM mean
= 100*(0.044–0.040)/0.040 = 10 (%)

initial EW wind perturbation (m/s) = measured eastward wind – GRAM mean eastward wind
= 14 – 20 = –6 m/s.

Similar calculations apply to the pressure, temperature, and other wind components.

For subsequent GRAM runs (in this example), this would start at 25 km, using *initpert* = 1, *rdinit* = 10.0, *ruinit* = –6.0 (and whatever values apply to the other initial perturbation components). These values ensure that the highest altitude (25 km) data point in the measured profile is consistent with the starting value (at 25 km) of the perturbed profile from GRAM07. If multiple perturbed profiles are desired for a Monte Carlo application, each is initialized with the same values (*rdinit* = 10.0 and *ruinit* = –6.0, etc.).

2.8 Optional Range Reference Atmosphere Data

The GRAM07 has the (optional) ability to use data (in the form of vertical profiles) from a set of 1983 or 2006 RRAs as an alternate to the usual GRAM climatology at RRA site locations. With this feature it is possible, for example, to simulate a flight profile that takes off from one RRA site (e.g. Edwards AFB), using the RRA atmospheric data, to smoothly transition into an atmosphere characterized by the GRAM climatology, then smoothly transition into an atmosphere characterized by a different RRA site (e.g. White Sands, NM), as the landing site.

The RRA data includes means and standard deviations of the various parameters at the RRA sites. Under the RRA option, when a given trajectory point is sufficiently close to a RRA site (lat-lon radius from a site less than *sitenear*, see below), the mean RRA data replace the mean values of the conventional GRAM climatology and the RRA standard deviations replace the conventional GRAM standard deviations in the perturbation model computations.

In addition to the RRA data files, a file called rrasites.txt is provided. This file gives file-code identifier, latitude, longitude, surface altitude, WMO site number, and site name, for each of the available 1983 and 2006 RRA sites. The file rrasites.txt must be augmented with comparable information for any new RRA sites that are provided by the user. Similarly, any site that the user wishes to have ignored when the RRA option is in use, must have its data line removed from the rrasites.txt file. Data for the RRA sites are provided in table 1.

NOTE: Latitude values are geodetic in the rrasites.txt file and the RRA data files. The GRAM07 input latitudes are geocentric. Internally, GRAM07 works with geocentric RRA site latitudes. If the RRA data option is used, the GRAM07 output file lists both geodetic and geocentric RRA site latitudes.

Use of the RRA data option in GRAM07 is controlled by several input parameters: (1) *rrapath* gives the name of the directory containing the RRA data; (2) *iurra* is the unit number to be used by the program for reading the RRA data; (3) code *iyrrra* is 1 if 1983 RRAs are to be used, or 2 if 2006 RRAs are to be used, and (3) *sitelim* and (4) *sitenear* control the size of the lat-lon region in the vicinity of any RRA site for which data from that RRA site is to be used. For any location having a radial distance (in lat-lon terms) of less than the value given by *sitenear*, the RRA data (with a full weight of 1) is used. For any location outside a lat-lon radius given by *sitelim*, the GRAM climatology data is used (i.e. a weight of 0 for the RRA data). Between radial distances of *sitenear* and *sitelim*, a weighted average of RRA and GRAM climatology data is used, ensuring a smooth transition from RRA data to GRAM data.

Nominal (default) values are *sitenear* = 0.5 degrees and *sitelim* = 2.5 degrees. For these values, any lat-lon within a radius of 0.5 degrees from any of the RRA sites, will use data from that RRA site. Any location beyond a radius of 2.5 degrees would use the GRAM climatology. Between 0.5 and 2.5 degrees radius, a weighted average of RRA data and GRAM data would be used, with the RRA data weight smoothly changing from 1 at a radius of 0.5 degrees to a weight of 0 at a radius of 2.5 degrees.

Depending on the value of *sitelim*, and the proximity of the various RRA sites used, it may be possible that a given trajectory location is in the vicinity of more than one RRA site (e.g. for locations near Point Mugu, Edwards AFB, and Vandenberg AFB). If a given trajectory location could be influenced by more than one RRA site, only data from the NEAREST (highest weight) site is used. NOTE that if, in such a situation, the user desires to ALWAYS use a specific RRA site (e.g. Edwards) and NEVER use a nearby RRA site (e.g. Point Mugu), then the name and information for the undesired nearby RRA site should be removed from the rrasites.txt file list.

RRA data apply from 0 to (at most) 70 km (above mean sea level). There is also a smooth interpolation process used to transition from the RRA data to GRAM data as the top of the RRA data is approached.

RRA data files for a given site consist of three data files, T1sssyy.txt, T2sssyy.txt, and T3sssyy.txt, where sss is the three-character site code from the list of sites given above, and yy = 83 for the 1983 RRA data and yy = 06 for the 2006 RRA data. The RRA data files are in the format given in the series of RRA reports (e.g. Document 361-83, Cape Canaveral Range Reference Atmosphere 0–70 km Altitude, February, 1983, Meteorology Group, Range Commanders Council). Files Txsssyy.txt correspond to table x (x = 1–3) in the RRA reports.

Each Txsssyy.txt file contains an annual average data set, as well as 12 monthly data sets. GRAM only uses the RRA data for the desired month and the annual average data are always ignored on read-in. The annual average data may either precede (1983 RRA data) or follow (2006 RRA data) the 12 monthly data sets. RRA table-1 data contain wind statistical parameters: height, mean eastward wind, standard deviation in eastward wind, correlation between eastward and northward wind(*), mean northward wind, standard deviation in northward wind, mean wind speed(*), standard deviation of the wind speed(*), skewness in wind speed(*), and number of observations(*). Asterisks denote parameters that are not used by GRAM.

RRA table-2 data contain thermodynamic statistical parameters: height, mean pressure, standard deviation in pressure, skewness in pressure(*), mean temperature, standard deviation in temperature, skewness in temperature(*), mean density, standard deviation in density, skewness in density(*), number of pressure observations(*), number of temperature observations(*), and number of density observations(*).

RRA table-3 data contain moisture related statistical parameters: height, mean vapor pressure(*), standard deviation in vapor pressure(*), skewness in vapor pressure(*), mean virtual temperature(*), standard deviation in virtual temperature(*), skewness in virtual temperature(*), mean dewpoint temperature, standard deviation in dewpoint temperature, skewness in dewpoint temperature(*), number of observations of vapor pressure and dewpoint temperature(*), and number of observations of virtual temperature(*). RRA table-4 data are not used in GRAM.

User-provided "RRA" data can also be used if the following conditions are followed: (1) Each new "RRA" site must be entered into the rrasites.txt file (maximum total number of sites allowed is 99). (2) The site code can be any three-character code not already being used, and the year for any new RRA data must be either 1983 or 2006. (3) Heights for any new RRA data must be in the range from 0 to 70 km, given in ascending order in the Txsssyy.txt files, with 300 or fewer heights entered (height increments can be any value, and fixed height increments do not have to be used). (4) The first data line of each Txsssyy.txt may have descriptive information (such as site name). However, the first data line of each file MUST contain the site latitude and longitude. (5) Latitude is given as xx.xxN or xx.xxS; longitude is given as xxx.xxE or xxx.xxW, in format (17X,F5.2,A1,2X,F6.2,A1). (6) Latitude and longitude values from the first data line are compared with the latitude and longitude in file rrasites.txt (given above), to ensure that the appropriate site data are being used. (7) In file rrasites.txt, north latitudes are positive (and south latitudes are negative), while east longitudes are positive (and west longitudes are negative). (8) Each Txsssyy.txt file may start or end with a set of annual average values. (9) Values for each of 12 monthly data sets must be provided. The annual and monthly averages may each have any number of lines of header information (as long as header information contains at least some character data and does not consist entirely of numbers). (10) The data lines may be in free-field format, but MUST contain a numerical value for each of the parameters expected, depending on the table type. (11) Parameters not used by GRAM (those indicated by asterisks, above) may be input as zero values (except for number of observations, which can be any number greater than zero). (12) Missing values (i.e. those that will be ignored) may be indicated by using 99.99 or 999.99.

2.9 Optional Global Gridded Upper Air Statistics Data

To characterize the lower atmosphere (0 to 27 km) GRAM07 uses either the original GUACA data (described in app. A) or a new set of data called the GGUAS (described in app. B).

The GUACA data include the period of record averages for 1980 to 1991 (accessed by using input option *iguayr* = 1), as well as individual years 1985 through 1991 (accessed by using *iguayr* = 2 and the specified year value). The GGUAS data contains only the longer period of record 1980 to 1995 (accessed by using *iguayr* = 3).

The ASCII-formatted GGUAS files are large (about 32 MB per month) and conversion is time-consuming. Therefore, GRAM07 is designed to use GGUAS data in binary form. A program, gguasrd.f, is supplied to read (once) the ASCII-formatted GGUAS data and convert to binary for subsequent use by GRAM07. GGUAS data consists of 12 files, one for each month of the period of record. The gguasrd.f program is used to read the GGUAS files (directly from the CD if desired by using the GGUAS directory D:\DATA if the CD ROM drive is D:\). The binary-converted files are named guabinmm.dat and mm is the month number. The binary output files are written to the same directory as the location of the gguasrd.f program. After binary-converted files are produced they should be arranged in the same directories and subdirectories as GUACA period-of-record data. Thus, if C:\guadir is the main GUACA directory, each binary GGUAS file guabinmm.dat is moved to the corresponding month's subdirectory C:\guadir\por\mm.

3. SAMPLE RESULTS

3.1 Revised Large-Scale Perturbations

Figure 5 illustrates an example of the new large-scale wave perturbation model. Amplitudes of the wave perturbations are randomly selected within reasonable bounds. Wavelengths are also established from a stochastic process in the GRAM code. The phase of the wave perturbation is initialized randomly from the starting random number seed. Thus, in a Monte Carlo run using various seed values, different phases of the wave perturbations are sampled.

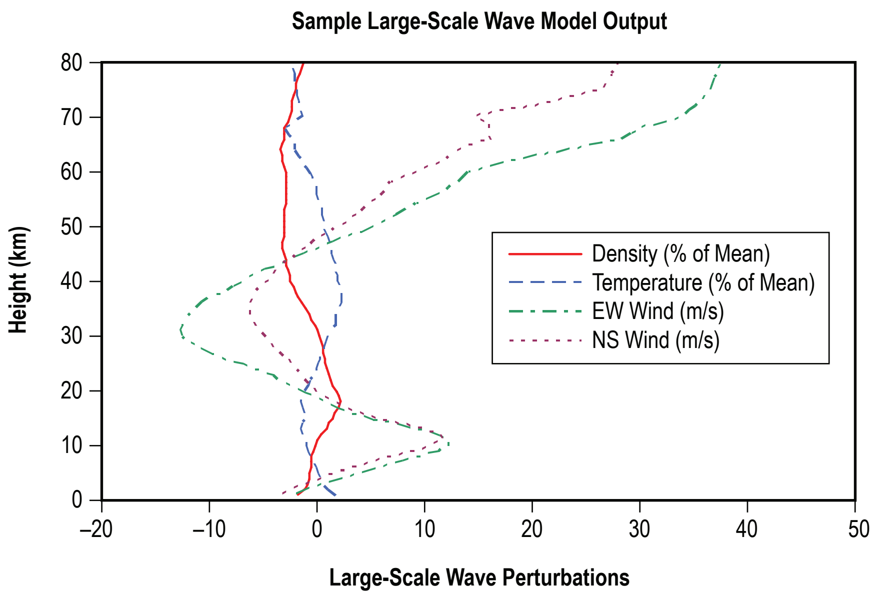

Figure 5. Sample vertical profile of wave-form large-scale perturbations.

Because the amplitudes and wavelengths of the wave perturbations depend on altitude, the waves are not purely sinusoidal in shape. Generally, the amplitude and wavelength increase as the altitude increases. The model automatically controls the relative phases of the various wave perturbations. Temperature and density wave perturbations tend to be roughly 180 degrees out of phase.

3.2 Revised Small-Scale Perturbations

As mentioned in section 1.3.1, the perturbation model was revised to provide a more realistic dispersion set. Figure 6 shows the results of a 1,000-profile Monte Carlo run of density perturbation versus height at the KSC. Also shown are the 2- and 3-sigma envelopes. It is evident from this plot that the dispersions (driven by the standard deviations) reach a local maximum at the jetstream altitudes (≈15 km) and then diminish before trending upward at the higher altitudes. Also apparent is the significant number of 2-sigma exceedances as well as a few beyond 3-sigma.

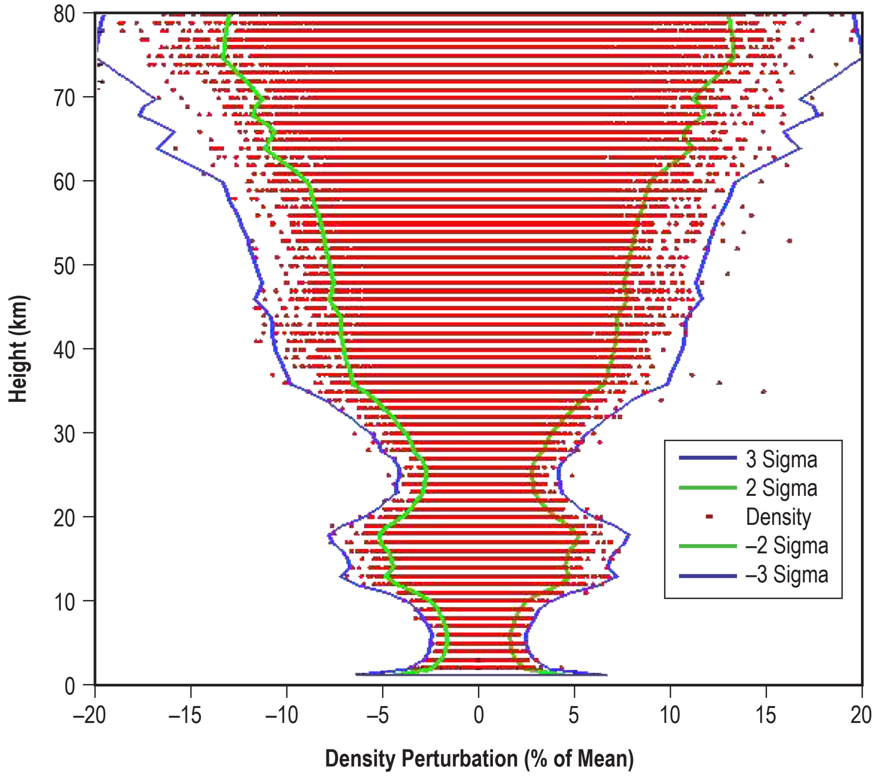

Figure 6. A plot of a 1,000 profile Monte Carlo runs of density perturbation (in percent of the mean value) as a function of height. The 2- and 3-sigma envelopes are also shown.

3.3 Perturbations in the Thermosphere

Marcos et al.[25] conducted a comparison between several thermosphere models, including MET and JB2006. The data used as "truth" for this comparison was from a high-accuracy set of thermospheric neutral densities, with one-day resolution, obtained from the tracking of 38 satellites. In figure 6a of Marcos et al[25] the mean data-to-model ratio is found to be within the approximate range 1.00 ± 0.03 over altitudes from 200 to 600 km, for both JB2006 and MET models. Their figure 6b demonstrates that MET has an altitude-increasing standard deviation of data-to-model ratio, with values of about 0.07 near 200 km, 0.15 near 400 km, and 0.27 near 600 km. Their figure also illustrates that JB2006 has somewhat better root-mean-square accuracy, with standard deviations of data-to-model ratio of about 0.05 near 200 km, 0.10 near 400 km, and 0.20 near 600 km.

Figure 7 shows results of a comparison of thermospheric density estimated with MET2007 and JB2006, as implemented in GRAM07. This figure shows density difference (JB2006-MET2007), in percent, as a function of altitude and latitude. Particular conditions illustrated in figure 7 are for January at 13 Hr local time, under low solar activity conditions (F10.7 = 70, ap = 5). Between 200 and 600 km, this figure shows that JB2006-versus-MET2007 density values are of about the same magnitude as the MET2007 standard deviations for data-to-model ratio, as found by Marcos et al.[25] Above 600 km, figure 7 shows that JB2006-MET2007 differences continue to increase

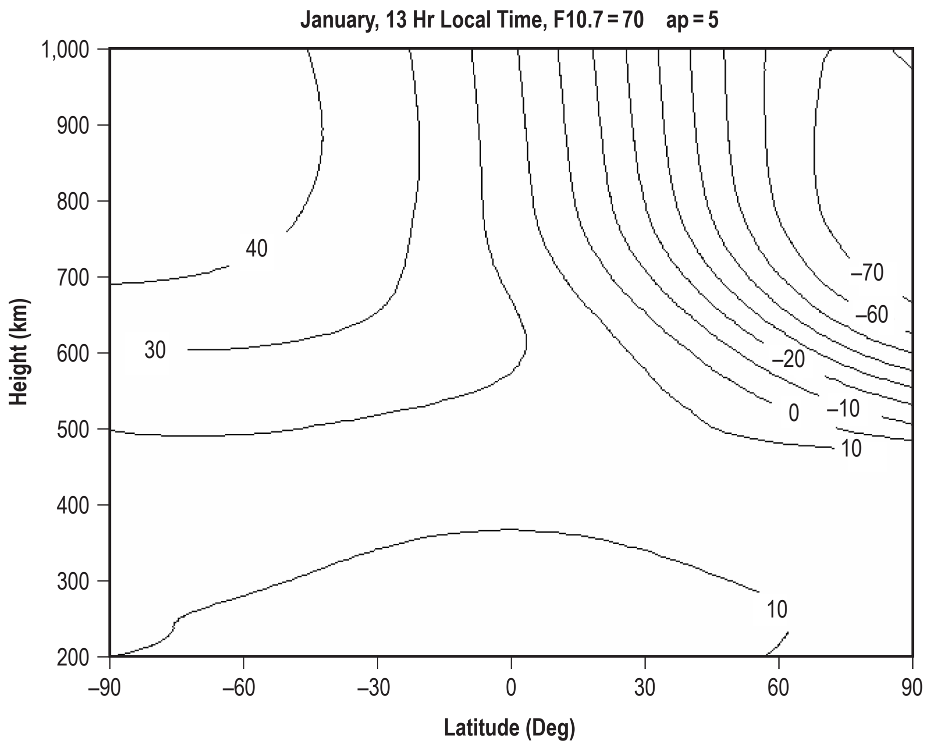

Figure 7. Density difference (percent) between JB2006 and MET thermosphere models in GRAM07, as a function of height and latitude: January, local time = 13 hours, and low solar conditions (F10.7 = 70, and ap = 5).

in magnitude, likely following a similar altitude increase in standard deviation of data-to-model ratio (which Marcos et al did not evaluate above 600 km).

Figure 8 is similar to figure 7, but for high solar activity conditions (F10.7 = 250, ap = 30). Comparison with figure 7 shows that that JB2006-MET2007 percentage differences in density are significantly smaller for high solar activity than for low solar activity, with differences exceeding 30 percent in magnitude only at latitudes poleward from 60° S, at altitudes above about 850 km.

Figure 9 gives a plot of lat-lon variation of JB2006-MET2007 density difference at an altitude of 400 km. Particular conditions illustrated in this figure are January, at a synoptic time of 13 Hr universal time coordinate (UTC), and high solar activity (F10.7 = 250, and ap = 30). Density differences exceed 16 percent in magnitude only at latitudes above about 70° N and longitudes within about ±60° of the equator. Again these results indicate that JB2006-MET2007 density differences are about the same as the absolute accuracy of MET2007 compared with density from satellite measurements.

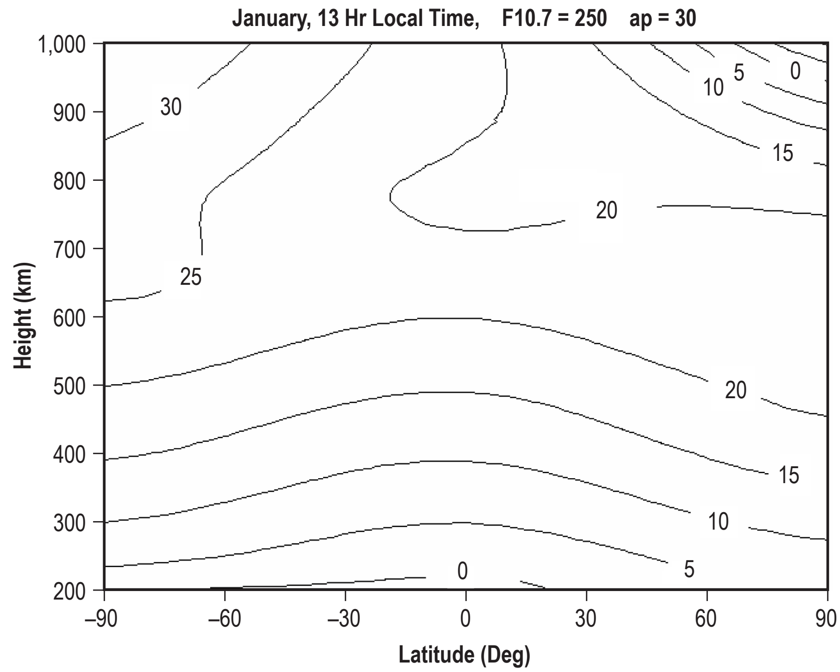

Figure 8. As in figure 7 for high solar conditions (F10.7 = 250, and ap = 30).

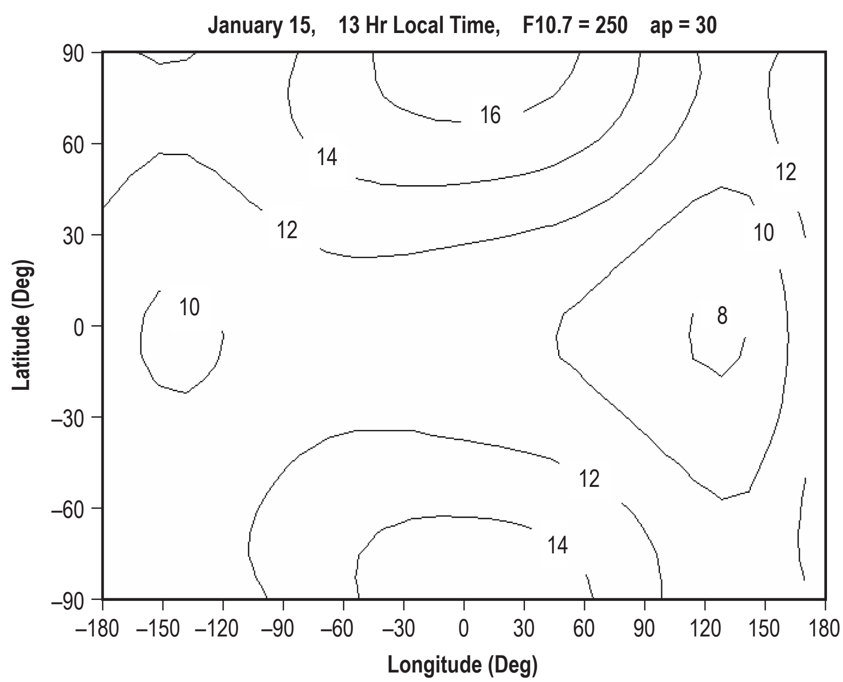

Figure 9. Density difference (percent) between JB2006 and MET thermosphere models in GRAM07, as a function of latitude and longitude at altitude 400 km: January, time = 13 hours UTC, and high solar conditions (F10.7 = 250, and ap = 30).

3.4 Range Reference Atmosphere Data Option

Section 2.8 describes the new RRA data option for GRAM07. A simplified example is illustrated in figures 10 and 11. For this example, a parabolic trajectory is assumed, with take-off from Edwards AFB, flying to an apogee at 100-km altitude, followed by a landing at White Sands Missile Range. Default values are used in this example. Hence, RRA values are used when the trajectory is within a lat-lon radius of 0.5 km from either of the RRA sites; GRAM climatology is used when the trajectory is beyond a lat-lon radius of 2.5 degrees from either RRA site; a smooth transition is assumed between RRA data and GRAM data between 0.5 and 2.5 degrees lat-lon radius.

Figure 10 illustrates the temperature profile between take-off and landing for a pure GRAM climatology trajectory (solid line) and the RRA/GRAM option (dotted line). Percentage differences between pure GRAM values and RRA/GRAM values of less than ± 2 are shown in figure 11.

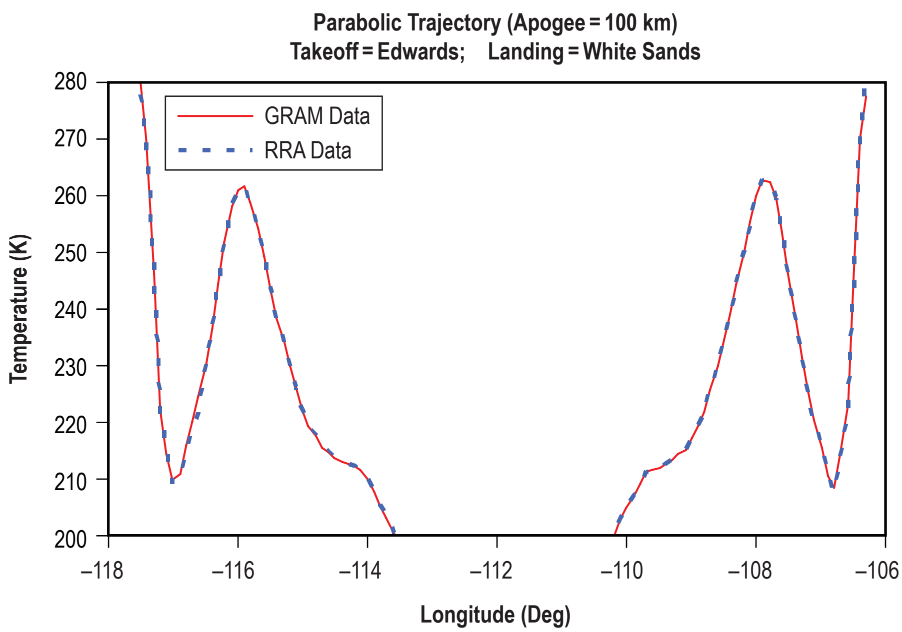

Figure 10. GRAM07 (solid line) or RRA/GRAM07 (dotted line) profiles of temperature along hypothetical parabolic trajectory between Edwards AFB and White Sands Missile Range with 100 km apogee.

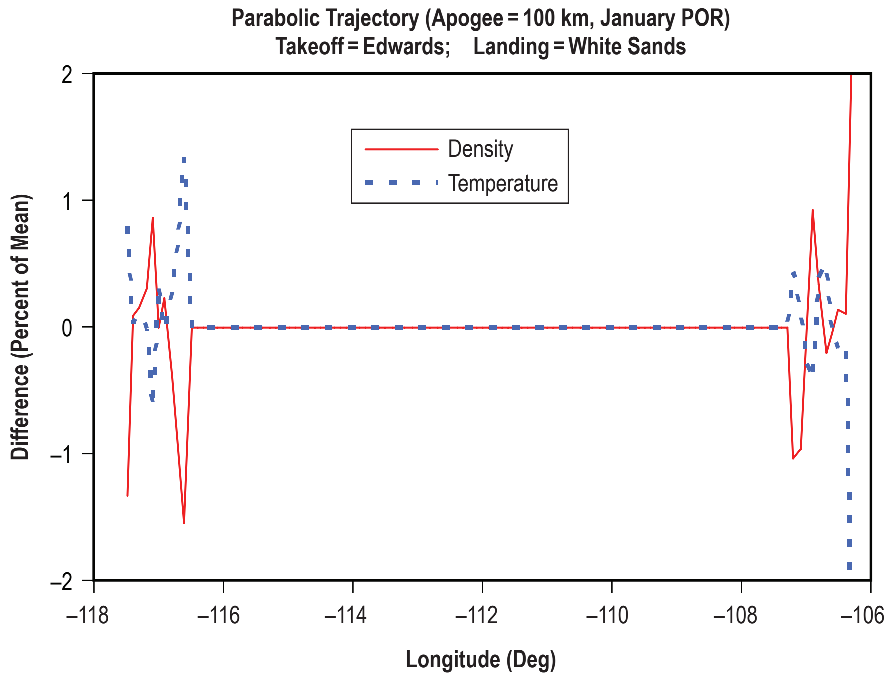

Figure 11. Differences in density (solid line) and temperature (dotted line) between GRAM07 and RRA/GRAM07 values for the hypothetical trajectory of figure 10.

4. GLOBAL REFERENCE ATMOSPHERIC MODEL07 USERS GUIDE

4.1 General Program Review

As with its predecessors, GRAM07, is designed to produce atmospheric parameter values either along a linear path (a profile), or along any set of related time-position data (a trajectory). Based on user-selected input values, the program can step automatically in height, latitude, longitude, and time along any desired linear profile. For the trajectory evaluation option, times and positions are provided to the program as a separate input (trajectory) file. Optionally GRAM07 can also be incorporated as a subroutine in the user's trajectory (or orbit propagation) code for evaluation along trajectory or orbital positions.

The GRAM07 uses two required input files and up to five other input files depending on user-selected options. Required files are the NAMELIST-formatted input file (app. D) and "atmosdat" (section 4.2). Optional input files for the lower atmosphere (0 to 27 km) are either the GUACA data (app. A) or GGUAS data (app. B). Optional RRA data input are described in section 2.8. Optional trajectory input file format is described in section 4.3. An optional auxiliary profile input is described in section 1.3.3. Different random number seeds are used in Monte Carlo analysis with a number of identical profiles or trajectories. A file of such seed numbers is described in section 4.4.

Output of GRAM07 consists of three files. For cases in which GRAM was incorporated as a subroutine in a user-provided trajectory code, there is an option to suppress all output from GRAM (GRAM-computed values handled as required in the users program (app. G)). The primary output file is the standard formatted output described in section 4.5.1 and appendix E. An optional species concentration output file (section 4.5.2 and app. E) can be produced. An optional specially formatted output file (section 4.5.3 and app. E) is designed to make it easy for the user to select from a wide range of output variables and to output them in an easily-modified format.

Path names for the input and output files (except the NAMELIST input file) are provided via input from the NAMELIST input file. Options selected in the NAMELIST input file determine which of the optional input and output files are actually used on a given program run.

4.2 The "atmosdat" Input File

The "atmosdat" file consists of several types of data in several formats easily readable as ASCII characters. The file requires a little more than 2.5 MB of disk storage.

4.2.1 Zonal-Mean Data

The zonal-mean data consists of 12 monthly sets of zonal-mean values for pressure, density, temperature, and zonal wind, tabulated at 10° latitude intervals from –90 to +90° and 5-km height increments from 20 to 120 km. Prefix codes, ZP, ZD, ZT, and ZU indicate pressure, density, temperature, and zonal wind, respectively. Each record contains the code, month, height in km, and –90°, –80°, ..., 80°, 90° latitude values of the parameter expressed as a four-digit integer with an exponent common to all values in the field appearing at the end of the record. Thus a value of 2,761 with an exponent at the end of the record of –6 would be the same as $2{,}761 \times 10^{-6} = 2.761 \times 10^{-3}$. Pressure data are in units of N/m^2, density values kg/m^3, temperatures K, and zonal winds m/s. The zonal-mean data set contains 1,008 Fortran-readable records, the code, and 22 integer values in each record (format A2, I4, I5, 19I6, I4).

4.2.2 Stationary Perturbations

The stationary perturbations are lat-lon dependent, relative perturbations, to be applied to the zonal-mean values. Data for each of 12 months are given for the northern and southern hemisphere latitudes. Prefix codes SP, SD, ST, SU, and SV indicate stationary perturbation values for pressure, density, temperature, zonal (eastward), or meridional (northward) wind components, respectively. Each record contains the code, month, height in km, latitude (–80 to +80) in degrees, and 18 values of stationary perturbations, in per mil (%/10) for thermodynamic variables, and 0.1 m/s for winds at longitude 180°, 160° W, 140° W, ..., 140° E, and 160° E. The monthly mean value, y_m, for parameter, y (pressure, density, or temperature), at any latitude and longitude is computed from the zonal-mean value, z_y, at the latitude and stationary perturbation, s_y (in per mil) at the latitude and longitude, by the relation

$$y_m = z_y \left(1 + s_y / 1{,}000\right) \tag{27}$$

For zonal (eastward) wind components, the monthly mean is $u_m = z_u + s_u$, while meridional (northward) mean winds are equal to the stationary perturbation value, i.e $v_m = s_y$. Note that the stationary perturbation values at 90° latitude are always zero. The stationary perturbation data consists of 15,300 Fortran-readable records with a code and 21 integer values in each record (format A2, 21I5).

4.2.3 Random Perturbations

Random perturbation magnitudes (standard deviations) are latitude-dependent only. Prefix codes RP, RD, RT, RU, and RV indicate random perturbation magnitudes in pressure, density, temperature, zonal wind, and meridional wind components, respectively. Each random perturbation record has the code, month, and height in km, followed by 19 values of random perturbation magnitude at 10° latitude increments from –90 to +90° followed by a common exponent value. These data give the relative standard deviations σ_p/p, σ_ρ/ρ, and σ_T/T (in percent) for use in the random perturbation model. The code RU and RV data are similar, except the wind perturbations are absolute deviations in m/s and cover the height range 0 to 200 km, whereas the RP, RD, and RT data cover 20 to 200 km. Random perturbation magnitudes for 0 to 27 km altitudes are provided by the GUACA database for both the thermodynamic and wind variables. The random perturbation data consist of 1,596 Fortran-readable records with code and 22 integer values in each record (format A2, I4, I5, 19I6, I4).

4.2.4 Large-Scale Fraction Data

From daily difference analysis described in section 2 of Justus et al.,[3] the fraction of the total variance (σ^2 from the random perturbation data) contained in the large-scale perturbations was determined as a function of height and latitude. The "atmosdat" file contains the annual average fraction (expressed as per mil) of total variance contained in the large-scale. Large- and small-scale magnitudes, σ_L and σ_S, are computed from the fractional data, f_L, in per mil (code PT for pressure, density, and temperature or code PW for winds), by the relations

$$\sigma_L = \left(f_L / 1{,}000\right)^{1/2} \sigma_T \tag{28}$$

$$\sigma_S = \left(1 - \left(f_L / 1{,}000\right)\right)^{1/2} \sigma_T \tag{29}$$

where σ_T is the total perturbation magnitude. The code PT and PW data sets contain 25 Fortran-readable records, with code word PT or PW, followed by 17 integer values in each record (format A2, 17I7) for code PT and 12 integer values (format A2, 12I7) for PW code records.

4.2.5 Density-Velocity Correlations

Daily difference analysis was also used to evaluate the cross correlations for use in the velocity perturbation model described in section 2 of Justus et al.[6] and in Justus et al.[3,4] Both large-scale and small-scale values of the density-velocity correlations were evaluated and are given in the "atmosdat" database (codes CL and CS) in per mil (i.e. divide by 1,000 to get correlations in the range –1 to +1). The code CL and CS data consist of 50 Fortran-readable records with code word CL or CS followed by 12 integer values in each record (format A2, 12I7).

All foregoing code values in the "atmosdat" database are ingested into the GRAM program through the subroutine setup in the initial_E07.f file.

4.2.6 Variable-Scale Random Perturbation Model Data

Variable-scale random perturbation model data appear next in the "atmosdat" database. They consist of 29 Fortran-readable records containing a code (RS) and 10 real (floating-point) values each (one height and nine associated parameters (section 2.6)), which are ingested into the GRAM program through the subroutine scalinit found in the initial_E07.f file. The format is A2, F5.0, 2F7.1, F7.2, F7.1, 5F7.2.

The remaining data in the "atmosdat" database are values needed for atmospheric constituent concentration calculations.

4.2.7 Langley Research Center Data

The next segment of data in the "atmosdat" database is the NASA LaRC concentration data[11] for the atmospheric constituent H_2O. The data consist of four groups of 35 Fortran-readable records of a code and nine data values each (one height and eight associated array values at latitudes –70 through +70°) and are ingested into the GRAM program through the subroutine concinit in the speconc_E07.f file. The four record groups present seasonal data at latitudes –70 through +70° for heights 6.5 through 40.5 km. Codes are LDJF for Dec-Jan-Feb, LMAM for Mar-Apr-May, LJJA for Jun-Jul-Aug, and LSON for Sep-Oct-Nov.

4.2.8 Air Force Geophysics Laboratory Data

The next-to-last segment of data in the "atmosdat" database is the AFGL concentration data[10] for the atmospheric constituents, H_2O, O_3, N_2O, CO, and CH_4. The data consist of five groups of 50 Fortran-readable records of six values each (one height and five associated array values for each of the five constituents) and are ingested into the GRAM program through the subroutine concinit. The five record groups present tropical (AFTR), mid-latitude summer (AFMS), mid-latitude winter (AFMW), sub-arctic summer (AFSS), and sub-arctic winter (AFSW) data. Tropical data are for latitudes of ±15°, mid-latitude data are for ±45°, and sub-arctic data are for ±60°. As necessary, a 6-month displacement is used to estimate southern hemisphere values from northern hemisphere values.

4.2.9 Middle Atmosphere Program Data

The last segment of data in the "atmosdat" database is the MAP concentration data[12] for the years 1979 to 83. The code O3 data are for ozone at 24 pressure levels (0.003 to 20 mb) for 12 months. Each of the 288 records consists of the code, month, pressure level (mb), and data values for 17 latitudes (-80 to +80°) and a common exponent value. The code H_2O data are for water vapor at 11 pressure levels (1.5 to 100 mb) for 12 months, followed by eight annual values (denoted by month 13) for the pressure levels 0.01 to 1.0 mb. There are a total of 140 H_2O records. Each contains the code, month, pressure level (mb), and five mean values at latitudes –60°, –45°, ±15°, +45° and +60° (with –60° estimated by 6-month displacement of +60° data), followed by five standard deviation values at these latitudes. The code N_2O data are for MAP nitrous oxide (code CH4 data for methane). The N_2O and CH_4 data consist of 204 records each. Each record contains the code, month (1 to 12), pressure level (17 levels, 0.1 to 20 mb), data at 15 latitudes (–70 to +70°) and a common exponent. The code OX data is for atomic oxygen at 19 altitudes (130 to 40 km) for each month. There are 228 total records, each containing the code, month, height (km), data values at 17 latitudes (–80 to +80°), and a common exponent. Units of the MAP code OX data are atoms/cm^3. The MAP code O3, H_2O, and CH_4 species data values are volume concentrations in units of ppmv while the code N_2O data are in parts per billion by volume (ppbv).

The LaRC and AFGL data are read in by subroutine concinit, while the MAP concentration data are read in by subroutine mapinit (both in the initial_E07.f file).

4.3 The Trajectory Input File

The trajectory file is only required when a trajectory rather than an automatically determined profile is desired. The file may contain an unlimited number of individual list-directed (free-field) records (i.e. lines) consisting of four real values of time (real seconds), height (km), latitude (±90°, with southern latitudes being negative), and longitude (±360°, with west longitudes being negative). Using the values in the first record of the trajectory file, the program evaluates the atmospheric parameters and continues looping back to read a new trajectory position until a position below the surface (height < 0.0) or the end of the file is reached.

4.4 Random Number Seed Input File

If a number of Monte Carlo simulations are to be computed in one program run, subsequent starting random number seed values are input via a special optional input file. The file contains one random seed number per line. Each random number seed value is an integer, ranging from 1 to 900,000,000. Random seed values do not have to be randomly-generated numbers. Thus, any convenient sequence of consecutive numbers may serve as valid random seed values.

4.5 Output Data Files

4.5.1 The Standard Formatted Output File

The standard output file (see an example in app. E) has header information consisting of the principal input data values and the Julian date required by the Jacchia section of the program and calculated internally by the program. Positions and times generated by the automatic linear profile feature, or as input by the trajectory input data, are listed on the output with the associated calculated values of the atmospheric variables. If a latitude greater than 90° in absolute magnitude is generated (or input), the transformation

$$\text{lat} = \left(180^\circ - |\text{lat}|\right)\left(\text{lat}/|\text{lat}|\right) \tag{30}$$

$$\text{lon} = \text{lon} - 180^\circ \tag{31}$$

is made. All longitudes are converted to the range –180 to +180° before being output.

The mean values of pressure, density, temperature, and wind components consist of either

(1) Values calculated from the GUACA database input if the height is 20 km or below.

(2) The sum of middle atmosphere zonal-mean plus stationary perturbation values if the height is between 27 and 90 km.

(3) A value faired between the GUACA data and zonal-mean plus stationary perturbations if the height is between 20 and 27 km.

(4) Thermosphere model values if the height is above 120 km.

(5) Faired values between middle atmosphere and the thermosphere model values if the height is between 90 and 120 km.

The percent deviations from the 1976 US Standard Atmosphere, on the "M-76" line, are evaluated by using standard atmosphere values computed by the subroutine, stdatm, in the gramsubs_E07.f file. The percent deviations are evaluated by the relations $100(T\text{-}T_S)/T_S$, $100(\rho - \rho_S)/\rho_S$, and $100(p - p_S)/p_S$, where the subscript *s* refers to the standard atmosphere values. This subroutine accurately reproduces the tabulated 1976 US Standard Atmosphere values within an accuracy of better than 0.2 percent above 90 km and even more accurately in the height region below 90 km where the molecular weight is constant. Since the 1976 US Standard Atmosphere is not defined above 1,000 km, the percent deviations output for heights above 1,000 km are zero. Because the thermosphere models are sensitive to solar activity conditions, large deviations from US Standard Atmosphere values can be produced in this height range for certain ranges of F10.7 and a_p values.

The parameter values output on the "Tot." line are the mean values defined above plus the random and wave model perturbations. These mean-plus-perturbation values represent typical "instantaneous" evaluations of the pressure, density, temperature, and winds. The percent deviations from the US Standard Atmosphere, on the "T-76" line are computed in the same way as the percent deviations of the monthly mean values from the standard atmosphere.

Values on the "H_2O" line are the mean water vapor values expressed as vapor pressure (N/m^2), vapor density (kg/m^3), dewpoint temperature (K), and relative humidity (%). Mean water vapor values are computed from the GUACA, LaRC, MAP, or AFGL data according to altitude. Fairing is used for a smooth transition between these data sources. Values on the "sigH" line are standard deviations in water vapor in the same units as the mean water vapor values.

The values on the "ranS," "ranL'" and "ranT" lines are the small-scale, large-scale, and total random perturbations evaluated at the output time and place. The values on the "sigS," "sigL," and "sigT" lines are standard deviations of the small-scale, large-scale, and total random components at the output time and place. According to the Gaussian distribution, on which the random perturbations are based, the perturbation values should be within the range $\pm\sigma$ 68 % of the time and outside the range $\pm\sigma$ 32 % of the time. Similarly, the perturbation values should be within the range $\pm 2\sigma$ 95 % of the time and outside the range $\pm 2\sigma$ 5 %. The values of the foregoing parameters are derived from the variable-scale perturbation model discussed in section 2.6.

4.5.2 The Species Concentration Output File

The species concentration output file (see an example in app. E) is also optional and controlled similarly to the special format output file by the value of an input parameter, *iuc*, and the pathname parameter, *conpath*. The file's header definition is found in the init subroutine of the initial_E07.f file, in the section near the labels 9091 and 9013, while the output definition is in the atmod subroutine of the models_E07.f file near the label 910.

4.5.3 The "Special" Format Output File

The "special" output file is optional, controlled by the input value of the *iopp* parameter switch and special output file pathname *nprpath* (app. D). As incorporated in the standard distributed code, this output file is configured at two separate locations. The file's header definition is found in the init subroutine of the initial_E07.f file, in the section near format label 954, while the file's parameter output definition is found in the atmod subroutine of the models_E07.f file, in the section near format 9000. The code at both locations may be modified to fit the requirements of the user.

As a further aid to constructing special output files appendix F gives tables listing the standard variables available for output. The tables are also given in the code in the atmod subroutine of the models_E07.f file following format label 910.

4.6 Description of Program Files and Subroutines

There are 12 source code files for the basic GRAM07 program (GRAM_E07.f, gramsubs_E07.f, guaca_E07.f, initial_E07.f, MET07prg_E07.f, models_E07.f, speconc_E07.f, random_E07.f, rramods_E07.f, MSISsubs_E07.f, HWMsubs_E07.f. and JB2006_E07.f). Many of these are basically described in Justus et al.[6] In addition to the programs that are required to run GRAM07, there are a number of utility codes that accompany the software. Brief descriptions of these GRAM07 program source code files and auxiliary source code files are:

gram_E07.f	Main GRAM07 program
gramsubs_E07.f	General GRAM07 subroutines
gramtraj_E07.f	Subroutine for use in user-provided trajectory program
guaca_E07.f	Reads and prepares GUACA data
HWMsubs_E07.f	Harmonic Wind Model (used with MSIS thermosphere model)
initial_E07.f	Reads atmosdat file and initializes data
JB2006_E07.f	Jacchia-Bowman 2006 model (Rev-A 10/06, with slight changes)
MET07prg_E07.f	The MET-07 model
models_E07.f	Other GRAM07 subroutines, not in gramsubs
MSISsubs_E07.f	Naval Research Labs MSIS (00) thermosphere model
multtraj_E07.f	Main driver (replaces gram_E07.f) program illustrating how to call GRAM07 to evaluate several different (multiple) trajectories in one program run
corrtraj_E07.f	Main driver (replaces gram_E07.f) program illustrating how to call GRAM07 to evaluate multiple profiles in one program run, with small-scale correlations preserved between the profiles
random_E07.f	Random number generators

rramods_E07.f	Reads the RRA data
speconc_E07.f	Species concentration subroutines
trajcalc_E07.f	Subroutines used in trajectory demonstration programs.
trajdemo_E07.f	Main driver (replaces gram_E07.f) in simple trajectory demonstration program
trajopts_E07.f	Main driver (replaces gram_E07.f) in example trajectory program that demonstrates several special options
bldtraj.f	Program to build pseudo-trajectory file for using in Earth-GRAM2007, to compute output for maps or crosssections.
gguasrd.f	Program to read the ASCII format GGUAS files (once) and write them in binary, for use by GRAM07.
timetraj.f	Program to generate a trajectory file consisting of any number of profiles separated by a user-selected time step.

4.7 Running Global Reference Atmospheric Model 07

Before running GRAM07, all files must be available in the proper configuration, and the source code (described in section 4.6) must be compiled and linked. For PC/Windows users, a GRAM executable file, GRAM_E07.exe is provided. If no changes to the code are required, then PC/Windows users can execute this program without re-compiling.

In addition, the various input files must be setup in directory structures. The GUACA or GGUAS data must be setup in directory and sub-directory structures described in appendices A and B, and the input pathname parameter *guapath* must point to this directory. Similarly, the input value for *atmpath* must point to the atmosdat file (section 4.2), the input pathname *trapath* to the trajectory file (section 4.3), the *rndpath* parameter to the random number seed file (section 4.4), and the pathname *rrapath* to the directory where the RRA data are located (section 2.8).

APPENDIX A—GLOBAL UPPER AIR CLIMATIC ATLAS DATA

(Adapted and expanded from the help file on the GUACA CDs)

A.1 Global Upper Air Climatic Atlas Background

The Global Upper Air Climatic Atlas Version 1.0 (GUACA), Volumes I & II, was produced at the Federal Climate Complex, Asheville, NC. Two organizations cooperated in developing GUACA:

1) Naval Oceanography Command Detachment (NAVOCEANCOM DET), a field activity of the Commander, Naval Oceanography Command.

2) National Climatic Data Center, a component of the National Oceanic and Atmosphereic Administration (NOAA) National Environmental Satellite Data and Information Service (NESDIS).

GUACA is a US Navy-led effort produced and funded under the authority of the Commander, Naval Oceanography Command (COMNAVOCEANCOM) and partially supported by funding under NOAA's Earth System Data and Information Management Program.

A.1.1 Data Sources

GUACA is based upon twice daily (00 & 12Z) upper air analyses provided by the European Center for Medium-Range Weather Forecasts (ECMWF) for the 1980 to 1991 period. Data were provided for a global 2.5° grid (10,512 grid points) and summarized by year-month and period of record-month. The observational data are used in the model initialization step for the forecasts produced by ECMWF. As part of the model initialization process, the data are subjected to quality control and observations at irregularly spaced locations are interpolated to regular 2.5° grid spacing.

The ECMWF located in Reading, England is funded and staffed by member European countries. Primarily responsible for forecast support for the European countries, ECMWF's data collection and assimilation system utilizes global data. A variety of data sources is used to produce the most accurate representation of the atmosphere at a given observation time.

These data sources include:

1) Radiosondes—balloon-borne instruments released by ground level observers (land and sea). The instrument package provides temperature, moisture, wind, and height data as the balloon rises through the atmosphere. Coverage is sparse over the global ocean environment.

2) Aircraft—reports of flight level wind, temperature, and moisture.

3) Satellites—atmospheric profiles of specific elements and estimates of wind data from cloud motion.

The ECMWF GUACA data provides monthly average gridded data for the following levels, meteorological elements, for each year noted, and for the 1980 to 1991 period of record:

Surface or Sea Level

Surface Air Temperature	1985-1991
Surface Dewpoint Temperature	1985-1991
Surface U and V Wind Components	1985-1991
Sea Level Pressure	1985-1991

Pressure Levels 1,000, 850, 700, 500, 400, 300, 250, 200, 150, 100, 70, 50, and 30 millibars

Air Temperature	1980-1991
Dewpoint Temperature (to 300 mb only)	1980-1991
Geopotential Height	1980-1991
U and V Wind Components	1980-1991

Pressure Level 10 mb

Air Temperature	1985-1991
Geopotential Height	1985-1991
U and V Wind Components	1985-1991

An approximate height above sea level for each pressure level is

1,000 millibars	130 meters	(400 feet)
850 millibars	1,500 meters	(5,000 feet)
700 millibars	3,000 meters	(10,000 feet)
500 millibars	5,500 meters	(18,000 feet)
400 millibars	7,000 meters	(24,000 feet)
300 millibars	9,000 meters	(30,000 feet)
250 millibars	10,500 meters	(34,000 feet)
200 millibars	12,000 meters	(40,000 feet)
150 millibars	13,500 meters	(44,000 feet)
100 millibars	16,000 meters	(52,000 feet)
70 millibars	18,500 meters	(60,000 feet)
50 millibars	21,000 meters	(69,000 feet)
30 millibars	24,000 meters	(78,000 feet)
10 millibars	31,000 meters	(101,000 feet)

Dewpoint temperature was calculated by the National Climatic Data Center (NCDC) from mixing ratio (to April 1982) and relative humidity (from April 1982 to end of period-of-record).

In addition to the above elements, atmospheric density for the surface to 10-millibar pressure level was calculated from pressure and temperature data. Also, vector and scalar wind and wind rose data were calculated from the u and v wind components (not used in GRAM).

It should be noted that the 70-mb level was missing in the GUACA 1980 data for April. This adversely affected the period-of-record density values for April at 70 mb. A routine has been included in GRAM to correct these period-of-record values. Because of the change in the number of levels and meteorological elements available after 1985, GRAM allows only the individual years 1985 to 1991 and the period-of-record data to be used.

The data analysis/forecast system used by ECMWF and the model initialization procedures undergo continual modification to better model the global atmosphere. The grid point analyses provided are not static and are considered evolutionary. The user should note that current year-month gridded data are considered to more accurately represent the real atmosphere. A number of major and minor changes have been introduced since 1980.

Dates of major changes and the effects on the gridded data are:

1) September, 1982—Temperature increase in the tropical middle troposphere—especially at 500 millibars.

2) May, 1985—Tropical temperature increase at 700 millibars, and decrease at 850 millibars, stratospheric temperature increase, with slight cooling at 300 millibars, warming in northern hemispheric polar region between 850 and 400 millibars, moisture increase at 850 millibars, with decrease above 850 millibars, improvements in tropical wind structure.

3) March, 1986—Significant moistening of the upper troposphere.

4) May, 1986—Tropical temperatures near tropopause decreased.

5) May, 1989—Moistening in upper troposphere (300 millibars).

An excellent overview of the ECMWF system and implemented changes can be found in Trenbreth.[26]

A.1.2 Accessing the Global Upper Air Climatic Atlas Compact Disc Data

The GUACA is a two CD-ROM disk product with year-month statistics for 1980 to 1987 on volume I and year-month statistics for 1985 to 1991 on volume II. Data for 1985 to 1987 plus the period-of-record statistics (1980 to 1991) are placed on both disks, to fill the disks to near capacity and to mitigate the need for “disc-swapping” if only a single disc CD-ROM reader is available to the user.

Since GRAM does not allow use of the individual years 1980 to 1984, only the GUACA CD volume II is of major interest to GRAM users. A personal computer (PC) disc-operated system (DOS-) based graphical display package is placed on both disks. Therefore, they can be used as stand-alone products. GRAM allows the GUACA data to be read in directly from the CD if a CD-ROM reader is available on the user's system

A.1.3 Global Upper Air Climatic Atlas Data Formats

Main GUACA directory: /CDROM/2p5deg

Year subdirectories: 1985 1986 1987 1988 1989 1990 1991 por

Monthly subdirectories: 01 02 03 04 05 06 07 08 09 10 11 12

Files in each monthly subdirectory:

Parameter	Units	File Name Mean Values	File Name Std. Devs.	Number of Levels	Size (bytes)
Density	g/m^3	mdenxx.dat	sdenxx.dat	15	315,660
Dewpoint Temperature	°C	mdwpxx.dat	sdwpxx.dat	7	147,404
Geopotential Height	m	mhgtxx.dat	shgtxx.dat	14	294,628
Sea Level Pressure	mb	mslpxx.dat	sslpxx.dat	1	21,212
Temperature	°C	mtmpxx.dat	stmpxx.dat	15	315,660
Eastward Wind Comp.	m/s	muwdxx.dat	suwdxx.dat	15	315,660
Northward Wind Comp.	m/s	mvwdxx.dat	svwdxx.dat	15	315,660

where xx = month (same as name of monthly subdirectory).

Example file pathname for January, period-of-record mean density:

/CDROM/2p5deg/por/01/mden01.dat

Each pressure level has data values for 144 longitudes (0°, 2.5°E, 5.0°E, ... 2.5°W) by 73 latitudes (–90°, –87.5°, ...+90°). Each data value is a two-byte integer. Each level of data values is preceded by a four-byte integer offset value and a four-byte real scale value. All data values are converted to physical units by the transform

Physical value = (data value × scale + offset)/100.

Each file begins with 180 bytes of header (in ASCII) that describes the parameter, units, and the pressure levels in the file. The amount of data in each pressure level (in bytes) is

bytes/level = $(2 \times 4) + (144 \times 73 \times 2) = 1,032$, and the size of each file (in bytes) is

file size = 180 + (21,032 × number of levels).

There are no embedded end-of-record (EOR) marks in the file.

If Fortran files can be opened as form='binary' (e.g., Microsoft Fortran) or form='system' (Silicon Graphics Incorporated (SGI) Fortran) (i.e. assuming no embedded EORs or other file management bytes), then each file could be read from the GUACA unit (*iug*) with the statements

```
Read(iug)(header(i),i=1,45)
Do 100 k = 1,numlevs
Read(iug,end=900)ioffset(k),scale(k),((input(i,j,k),
& i=1,144),j=1,73)
100     continue
```

(assuming the header array has been declared as Character*4, and the input array has a number of levels = numlevs). The GUACA reading routine in GRAM uses the more standard, form='unformatted' for the file open statements. By declaring the GUACA files as direct access, with a fixed record size of one (four-byte) word each, the GUACA read routine provided in GRAM can still read the files directly on some platforms (e.g. Silicon Graphics Inc. (SGI) Unix). For systems that must treat the files as some other fixed-block (record) size (e.g. 512-byte blocks on a VAX), the option is provided to pre-read the GUACA files and write them out to direct access, internal files that can be read in records, each consisting of one four-byte word. This method loses some in run-time efficiency but provides for more inter-system portability (i.e. for those systems that do not allow the form='binary' or form='system' file opens). Although the more efficient reading process noted above, takes about half the time, the read routine in GRAM takes a few seconds to read each file on an SGI Unix platform.

A.1.4 Credits

The following people contributed to the GUACA project:

NAVAL OCEANOGRAPHY COMMAND DETACHMENT
Program Direction: LCDR Dennis B. Ruth, USN
Program Concepts: Mr. Brian L. Wallace

NATIONAL CLIMATIC DATA CENTER
Programming: Mr. Claude N. Williams, Jr.
Mr. Eric B. Gadberry
Technical Support: Mr. Michael J. Changery

To purchase a copy of GUACA CD-ROM contact:

National Climatic Data Center 1
51 Patton Avenue, Room 120
Attn: Climate Services Division
Federal Building
Asheville, NC 28801-5001
Phone: (704) 271-4800
Fax: (704) 271-4876
E-mail: orders@ncdc.noaa.gov
Internet: <http://www.ncdc.noaa.gov/cdrom/cdrom.html#ORDER>

APPENDIX B —DATABASE DESCRIPTION FOR GLOBAL GRIDDED UPPER AIR STATISTICS

VERSION 1.1
March 1996

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B.1 Introduction

B.1.1 Background

The GGUAS master database was developed as source data to be coupled with a software access and display package and to be distributed as a two-volume CD-ROM product entitled "Global Upper Air Climatic Atlas." This CD-ROM product, completed in April 1993, provides a versatile interface enabling the user to select and contour a nearly unlimited variety of climatological charts covering the global upper air environment. Although export of the gridded data is possible from within the CD, users requiring massive data export preferred direct access to the GGUAS database. Version 1 of this CD-ROM product provided access to data for the original period of record, 1980 to 1991. Version 1.1 updates the period of record to 1980 to 1995.

B.2 Global Gridded Upper Air Statistics

B.2.1 Scope

The GGUAS data set describes the atmosphere for each month of the year represented on a 2.5-degree global grid at 15 standard pressure levels. Mean and standard deviation values were compiled for sea level pressure, wind speed, air temperature, dewpoint, height and density. Eight-point wind roses were also compiled.

B.2.2 Source

Source of the GGUAS data set was the ECMWF 0000Z and 1200Z gridded analyses available through and archived at the NCDC. Analyses are currently provided under the auspices of the Tropical Ocean Global Atmosphere (TOGA) project sponsored by the WMO. The GGUAS data set was derived from analyses for 1980 to 1995.

B.2.3 Coverage/Resolution

The GGUAS data set covers the entire globe. The spatial resolution is a 73 by 144 grid spaced at 2.5 degrees, providing a resolution of approximately 100 km in the middle latitudes. Temporal resolution is one month.

B.2.4 Organization

The GGUAS data is in the subdirectory called DATA. For each of 12 months/10 512 grid points/15 levels in the atmosphere, the data set contains a mean and standard deviation of each of seven elements and an eight-point wind rose.

B.2.5 Stored Parameters

Table 2 lists data parameters stored in the GGUAS data set for each grid point.

Table 2. Global gridded upper air statistics parameters.

Parameter Name	Precision	Value Range
Month	1	00 to 12
Year	1	00 to 99 (SS – POR)
Level	1	SURF, 1,000, 850, 700, 500, 400, 300, 250, 200, 150, 100,70, 50, 30, 10
Latitude	0.1	–90.0 to 90.0
Longitude	0.1	0.0 to 357.5 (eastward)
Larger of Number of Occurrences at a Level of U, V, Air Temp, or Height	1	>0

Table 2. Global gridded upper air statistics parameters (Continued).

Parameter Name	Precision	Value Range
U E-W Component of Wind Speed Mean Standard Deviation	 0.1 0.1	 –99.9 to 99.9 .0 to 99.9
V N-S Component of Wind Speed Mean Standard Deviation	 0.1 0.1	 –99.9 to 99.9 .0 to 99.9
Vector Wind Speed Mean Standard Deviation	 0.1 0.1	 .0 to 99.9 .0 to 99.9
Scalar Wind Speed Mean Standard Deviation	 0.1 0.1	 .0 to 99.9 .0 to 99.9
Correlation of Coefficients of Wind Components	0.1	–0.9 to 99.9
Air Temperature Mean Standard Deviation	 0.1 0.1	 –999.9 to 999.9 .0 to 9,999.9
Dewpoint Temperature Mean Standard Deviation	 0.1 0.1	 –999.99 to 999.9 .0 to 9,999.9
Height Mean Standard Deviation	 0.1 0.1	 –350.0 to 99,999.9 .0 to 99,999.9
Density Mean Standard Deviation	 0.0001 0.0001	 .0 to 9.9999 .0 to 9.9999
Mean Wind Speed for 45° Sector Centered on 0°	0.1	.0 to 999.9
Percent Occurrence of Wind Direction Within 45° Sector Centered on 0°	0.1	.0 to 999.9
Mean Wind Speed for 45° Sector Centered on 90°	0.1	.0 to 999.9
Percent Occurrence of Wind Direction Within 45° Sector Centered on 90°	0.1	.0 to 999.9
Mean Wind Speed for 45° Sector Center on 135°	0.1	.0 to 999.9
Percent Occurrence of Wind Direction Within 45° Sector Centered on 135°	0.1	.0 to 999.9
Mean Wind Speed for 45° Sector Centered on 180°	0.1	.0 to 999.9
Mean Wind Speed for 45° Sector Centered on 225°	0.1	.0 to 999.9
Percent Occurrence of Wind Direction Within 45° Sector Centered on 225°	0.1	.0 to 999.9
Mean Wind Speed for 45° Sector Centered 270°	0.1	.0 to 999.9
Percent occurrence of Wind Direction Within 45° Sector Centered on 270°	0.1	.0 to 999.9
Mean Wind Speed for 45° Sector Centered on 315°	0.1	.0 to 999.9
Percent Occurrence of Wind Direction Within 45° Sector Centered on 315°	0.1	.0 to 999.9
Percent Occurrence of CALM	0.1	.0 to 999.9

B.2.6 Data Quality

The GGUAS data set was derived from the twice-daily analyses produced by ECMWF. The data summaries cover 1980 to 1995 for each element during this period with the exception of sea level pressure, surface and 10-mb elements that are only available for 1985 to 1995. Questionable elements (based on quality control procedures) were deleted prior to summarization. The large number of observations to compute the summaries provides an indication of the reliability of the data.

B.2.7 Points of Contact

Concerning using the CD-ROM

Climate Applications Branch
National Climatic Data Center
151 Patton Ave, Room 468
Asheville, NC 28801-5001
(704) 271-4702

Concerning the data, or to purchase a copy of the CD-ROM or other data

Climate Services Division
National Climatic Data Center
151 Patton Ave
Asheville, NC 28801-5001
(704) 271-4800
orders@ncdc.noaa.gov

B.3 Database Format and Read Instructions

B.3.1 General

Each data record contains all elements at each level for a month at a grid point.

B.3.2 Read Instructions with Format

Data Record	Format
MONTH	I2
YEAR (XX = POR)	A2
LEVEL (MILLIBARS)	A4
LATITUDE (DEGREES TO TENTHS) (POSITIVE FOR NORTH)	F5.1
LONGITUDE (DEGREES TO TENTHS)	F6.1
OBS COUNT	I4
U, MEAN EAST-WEST COMPONENT OF WIND SPEED (M/SEC) (POSITIVE FROM WEST)	F5.1
STANDARD DEVIATION OF EAST-WEST COMPONENT OF WIND SPEED (M/SEC)	F5.1

Data Record	Format
V, MEAN NORTH-SOUTH COMPONENT OF WIND SPEED (M/SEC) (POSITIVE FROM SOUTH)	F5.1
STANDARD DEVIATION OF NORTH-SOUTH COMPONENT OF WIND SPEED (M/SEC)	F5.1
VECTOR MEAN (M/SEC)	F5.1
VECTOR STANDARD DEVIATION (M/SEC)	F5.1
MEAN SCALAR WIND (M/SEC)	F5.1
STANDARD DEVIATION OF SCALAR WIND (M/SEC)	F5.1
CORRELATION COEFFICIENT OF WIND COMPONENTS	F6.1
MEAN AIR TEMPERATURE (DEGREES C)	F6.1
STANDARD DEVIATION OF AIR TEMPERATURE (DEGREES C)	F6.1
MEAN DEWPOINT TEMPERATURE (DEGREES C)	F6.1
STANDARD DEVIATION OF DEWPOINT TEMPERATURE (DEGREES C)	F6.1
MEAN HEIGHT (METERS) (If level = SURF, then Mean Sea Level pressure (mb))	F7.1
STANDARD DEVIATION OF HEIGHT (METERS)	F7.1
MEAN DENSITY (KG/M**3)	F6.4
STANDARD DEVIATION OF DENSITY (KG/M**3)	F6.4
MEAN WIND SPEED FOR 45 DEGREE SECTOR CENTERED ON 0 DEGREES (M/SEC)	F5.1
PERCENT OCCURRENCE OF WIND DIRECTION WITHIN 45 DEGREE SECTOR CENTERED ON 0 DEGREES	F5.1
MEAN WIND SPEED FOR 45 DEGREE SECTOR CENTERED ON 45 DEGREES (M/SEC)	F5.1
PERCENT OCCURRENCE OF WIND DIRECTION WITHIN 45 DEGREE SECTOR CENTERED ON 45 DEGREES	F5.1
MEAN WIND SPEED FOR 45 DEGREE SECTOR CENTERED ON 90 DEGREES (M/SEC)	F5.1
PERCENT OCCURRENCE OF WIND DIRECTION WITHIN 45 DEGREE SECTOR CENTERED ON 90 DEGREES	F5.1
MEAN WIND SPEED FOR 45 DEGREE SECTOR CENTERED ON 135 DEGREES (M/SEC)	F5.1
PERCENT OCCURRENCE OF WIND DIRECTION WITHIN 45 DEGREE SECTOR CENTERED ON 135 DEGREES	F5.1
MEAN WIND SPEED FOR 45 DEGREE SECTOR CENTERED ON 180 DEGREES (M/SEC)	F5.1
PERCENT OCCURRENCE OF WIND DIRECTION WITHIN 45 DEGREE SECTOR CENTERED ON 180 DEGREES	F5.1
MEAN WIND SPEED FOR 45 DEGREE SECTOR CENTERED ON 225 DEGREES (M/SEC)	F5.1
PERCENT OCCURRENCE OF WIND DIRECTION WITHIN 45 DEGREE SECTOR CENTERED ON 225 DEGREES	F5.1
MEAN WIND SPEED FOR 45 DEGREE SECTOR CENTERED ON 270 DEGREES (M/SEC)	F5.1
PERCENT OCCURRENCE OF WIND DIRECTION WITHIN 45 DEGREE SECTOR CENTERED ON 270 DEGREES	F5.1
MEAN WIND SPEED FOR 45 DEGREE SECTOR CENTERED ON 315 DEGREES (M/SEC)	F5.1
PERCENT OCCURRENCE OF WIND DIRECTION WITHIN 45 DEGREE SECTOR CENTERED ON 315 DEGREES	F5.1
PERCENT OCCURRENCE CALM	F5.1
* Exception: If a grid point has no GGUAS data for a given element/level/month, the field has a negative sign with 9s filling the remainder of the field.	

FORMAT

I2, A2, A4, F5.1, F6.1, I4, 8(F5.1), 5(F6.1), 2(F7.1), 2(F6.4), 17(F5.1)

The ASCII data are organized as 204 characters per record. (Note: A CR/LF is included at the end of each record with an additional two bytes.)

APPENDIX C—COMPILING AND RUNNING GLOBAL REFERENCE ATMOSPHERIC MODEL 07

C.1 General Introduction

GRAM07 can be run in stand-alone mode (i.e. as an independent program), or as a set of subroutines in a user-provided program, such as a trajectory code. The following material gives several examples of how to compile and run GRAM07 in each of these modes. Examples are given for both PC and Unix machines. If you wish to run stand-alone GRAM on a PC, and do not need to make any code changes, you can use PC-executable files provided on the distribution CD. It is necessary to compile the GRAM07 source code (1) if you wish to run on a Unix or other non-PC platform, (2) if you make changes in the code (e.g. by selecting other/additional parameters for output), or (3) if you want to incorporate GRAM07 as subroutines in your own code, such as a trajectory program. Unless otherwise noted below, it is assumed in the following material that all files from the distribution CD have been copied to folders as named in the instructions for how to setup GRAM07.

C.1.1 Command-Line Compiling on a PC

One example of how to compile GRAM07 on a PC/Windows system is to use command line mode. Command line mode is initiated by clicking on "Start," then "Run," then entering "CMD.EXE" (without the quotes) in the run window. For Fortran Powerstation version 4, the compile-and-link command is "fl32." Therefore, with that compiler, stand-alone GRAM can be compiled (to an executable file named gram_E07.exe) by entering the following command:

```
fl32 gram_E07.f gramsubs_E07.f guaca_E07.f initial_E07.f MET07prg_E07.f
  models_E07.f random_E07.f speconc_E07.f rramods_E07.f MSISsubs_E07.f
  HWMsubs_E07.f JB2006_E07.f
```

Other compilers will have different commands for doing command-line compile operations. Compilers also generally provide a "Programmer's Workbench" or similar graphical-user-interface mode for doing program compile-and-link operations.

Subroutines trajcalc_E07.f and gramtraj_E07.f and three main drivers (trajdemo_E07.f, trajopts_E07.f, and multtraj_E07.f) are provided, to give several examples of how to incorporate and use GRAM07 as subroutines in you own code. A driver program corrtraj_E07.f, similar to multtraj, is also provided. The corrtraj program evaluates multiple profiles in one program run, with small-scale correlations preserved between the profiles, whereas small-scale correlations between trajectories are not maintained in the multtraj program. Extensive comments in these example driver routines provide more details. To compile these example "trajectory" codes (using the Fortran Powerstation "fl32" command), enter each of the following command lines:

```
fl32 trajdemo_E07.f trajcalc_E07.f gramtraj_E07.f gramsubs_E07.f
  guaca_E07.f initial_E07.f MET07prg_E07.f models_E07.f random_E07.f
  speconc_E07.f rramods_E07.f MSISsubs_E07.f HWMsubs_E07.f JB2006_E07.f

fl32 trajopts_E07.f trajcalc_E07.f gramtraj_E07.f gramsubs_E07.f
  guaca_E07.f initial_E07.f MET07prg_E07.f models_E07.f random_E07.f
  speconc_E07.f rramods_E07.f MSISsubs_E07.f HWMsubs_E07.f JB2006_E07.f

fl32 multtraj_E07.f trajcalc_E07.f gramtraj_E07.f gramsubs_E07.f
  guaca_E07.f initial_E07.f MET07prg_E07.f models_E07.f random_E07.f
  speconc_E07.f rramods_E07.f MSISsubs_E07.f HWMsubs_E07.f JB2006_E07.f

fl32 corrtraj_E07.f gramtraj_E07.f gramsubs_E07.f guaca_E07.f
  initial_E07.f MET07prg_E07.f models_E07.f random_E07.f speconc_E07.f
  rramods_E07.f MSISsubs_E07.f HWMsubs_E07.f JB2006_E07.f
```

C.1.2 Compiling on a Unix Machine

The Unix f77 command can be used to compile GRAM07, to an executable named gram_E07.x, by entering the following:

```
f77 gram_E07.f gramsubs_E07.f guaca_E07.f initial_E07.f MET07prg_E07.f
  models_E07.f random_E07.f speconc_E07.f rramods_E07.f MSISsubs_E07.f
  HWMsubs_E07.f JB2006_E07.f
mv a.out gram_E07.x
```

Similarly, the f77 command may also be used to compile the three programs that provide examples of how to incorporate GRAM07 in user code:

```
f77 trajdemo_E07.f trajcalc_E07.f gramtraj_E07.f gramsubs_E07.f
  guaca_E07.f initial_E07.f MET07prg_E07.f models_E07.f random_E07.f
  speconc_E07.f rramods_E07.f MSISsubs_E07.f HWMsubs_E07.f JB2006_E07.f
mv a.out trajdemo_E07.x

f77 trajopts_E07.f trajcalc_E07.f gramtraj_E07.f gramsubs_E07.f
  guaca_E07.f initial_E07.f MET07prg_E07.f models_E07.f random_E07.f
  speconc_E07.f rramods_E07.f MSISsubs_E07.f HWMsubs_E07.f JB2006_E07.f
mv a.out trajpots_E07.x

f77 multtraj_E07.f trajcalc_E07.f gramtraj_E07.f gramsubs_E07.f
  guaca_E07.f initial_E07.f MET07prg_E07.f models_E07.f random_E07.f
  speconc_E07.f rramods_E07.f MSISsubs_E07.f HWMsubs_E07.f JB2006_E07.f
mv a.out multtraj_E07.x
```

```
f77 corrtraj_E07.f gramtraj_E07.f gramsubs_E07.f guaca_E07.f
  initial_E07.f MET07prg_E07.f models_E07.f random_E07.f speconc_E07.f
  rramods_E07.f MSISsubs_E07.f HWMsubs_E07.f JB2006_E07.f
mv a.out corrtraj_E07.x
```

C.1.3 Running in Command-Line Mode on a PC

The following assumes that the PC executable files are in folder C:\EarthGRAM07\PC_Executables, and the example input/output files are in folder C:\EarthGRAM07\PC_IOfiles. GRAM07 can easily be run from any directory. For example, to run from a directory named C:\MyTest, do the following:

(1) Copy (and edit and/or rename, if desired) the file C:\EarthGRAM07\PC_IOfiles\NameRef.txt to the C:\MyTest folder. Note that NAMELIST input file names are limited to 32 characters.

(2) Open a PC command-line window by clicking start and run and entering the command CMD.EXE.

(3) Change the directory by entering the commands C: and CD \MyTest.

(4) Execute GRAM07 by entering the command C:\EarthGRAM07\PC_Executables\gram_E07.exe.

(5) Enter the name of the input file (from step 1) when prompted.

(6) Output files will appear in the C:\MyTest folder.

If file open errors are encountered, make sure that file pathnames are properly set in the NAMELIST input file. For files residing in folders as described above, set the following path names in the NAMELIST input file:

```
 atmpath = 'C:\EarthGRAM07\PC_IOfiles\atmosdat.txt'
 guapath = 'C:\EarthGRAM07\GUACAdata'
   if the GUACA data are to be read from the C: drive, or
 guapath = 'E:\2P5DEG'
   if the GUACA data are to be read from the GUACA CD on the E: drive.
```

For test or demonstration purposes, it is also possible to run GRAM07 directly from the distribution CD (provided that only January period-of-record GUACA input data are required). To do this, from the C:\MyTest directory, as above, simply replace "C:\EarthGRAM07\" with "E:\" (assuming that E: is the CD drive) in the command and input pathnames for the executable file, the atmosdat.txt file, and the GUACA path name. See a later discussion on how to set file path names if using the input trajectory option, the RRA input option, the auxiliary profile input option, and/or the multiple-profile Monte Carlo option. Output file path names can be any name specified by the user. All path names are limited to 64 characters in length.

C.1.4 Running in Command-Line Mode on a Unix Machine

Unix executable files must be compiled and created, as discussed above. For example, the GRAM07 Unix executable is created and named gram_E07.x in directory /usr/EarthGRAM07/UNIX_Executables. The following assumes that the example input/output files are placed in folder /usr/EarthGRAM07/UNIX_IOfiles. GRAM07 can easily be run from any directory. For example, to run from a directory named /usr/MyTest, do the following:

(1) Copy (and edit and/or rename, if desired) the file /usr/EarthGRAM07/UNIX_IOfiles/NameRef.txt to the /usr/MyTest folder. Note that NAMELIST input file names are limited to 32 characters.

(2) Change directory by entering the command cd /usr/MyTest.

(3) Execute GRAM07 by entering the command /usrEarthGRAM07/UNIX_Executables/gram_E07.x.

(4) Enter the name of the input file (from step 1) when prompted.

(5) Output files will appear in the /usr/MyTest folder.

If file open errors are encountered, make sure that file pathnames are properly set in the NAMELIST input file. For files residing in folders, set the following path names in the NAMELIST input file:

atmpath = '/usr/EarthGRAM07/UNIX_IOfiles/atmosdat.txt'
guapath = '/usr/EarthGRAM07/GUACAdata'
if the GUACA data are to be read from the /usr/EarthGRAM area, or
guapath = '/CDROM/2P5DEG'
if GUACA data are to be read from the GUACA CD on the /CDROM/ drive

See the later discussion on how to set file path names if using the input trajectory option, the RRA input option, the auxiliary profile input option, and/or the multiple-profile Monte Carlo option. Output file path names can be any name specified by the user. All path names are limited to 64 characters in length.

C.1.5 Reference Input/Output Files for Testing

To facilitate runtime testing, a NAMELIST-formatted reference input file, NameRef.txt, is provided on the distribution CD-ROM. Both PC versions and Unix versions are provided (in folders EarthGRAM07\PC_IOfiles and EarthGRAM07\UNIX_IOfiles, respectively, on the distribution CD). PC and Unix-version reference output files are also provided (OutputRef.txt and SpeciesRef.txt on the distribution CD). If a test run (as described in the above sections) is done using input file NameRef.txt, to produce output files named output.txt and species.txt, these output files can be tested against the reference output files provided. On a PC (from the directory where the test output files reside), to compare against reference files on the CD (E: drive), enter PC commands:

fc output.txt E:\PC_IOfiles\OutputRef.txt

fc special.txt E:\PC_IOfiles\SpecialRef.txt

and

fc species.txt E:\PC_IOfiles\SpeciesRef.txt

Any file differences will be noted in the output from the fc (file compare) command. To do the same tests on a Unix machine, the commands are

diff output.txt /CDROM/OutputRef.txt

diff special.txt /CDROM/SpecialRef.txt

and

diff species.txt /CDROM/SpeciesRef.txt

Be sure to compare against files from the appropriate directory on the distribution CD, since there are differences in the PC and Unix version reference output files. In Unix format, numbers that are less than 1 (in magnitude) are written (0.xxx -0.xxx etc.). In the PC environment, such numbers are written without the leading zeroes (i.e. .xxx -.xxx etc.). Because of variations in handling of round-off by different operating systems and/or compilers, a few numbers in the reference output files may differ from those in the user-generated test output files. Such differences should be no larger than about 1 in the last significant digit of the output.

C.1.6 Running with an Input Trajectory File

To run the stand-alone GRAM07 program with a pre-computed input trajectory file of positions and times, set the trajectory file pathname (*trapath*) in the NAMELIST input file to whatever file name is desired, set the number of computed positions (*nmax*) to zero, and set the trajectory file unit number (*iopt*) to any nonconflicting value. The trajectory file contains one time and position per line, having values for elapsed time (seconds), height (km), latitude (degrees, north positive), and longitude (degrees, east positive). Trajectory input heights greater than 6,000 km are treated as geocentric radius values, rather than as altitudes above reference ellipsoid. Example programs illustrating how to drop GRAM into trajectory code cannot be run with trajectory file input, since trajectory positions are generated “on the fly” in these programs.

C.1.7 Running Multiple Profiles/Trajectories in Monte Carlo Mode

Multiple profiles or trajectories can be computed in one run of the program, in a Monte Carlo simulation of various perturbation profiles, by providing input for any number of random seed values. Input random seeds are provided, with one seed value per line, in a file whose path name is specified by input parameter *rndpath*, the file unit number for which is specified by input parameter *iun*. Integer random seed values must be in the range 0 <= seed <= 900,000,000. Other aspects of the perturbation model can be controlled by input parameters *rpscale*, *initpert*, *patchy*, *rpinit*, *rdinit*, *rtinit*, *ruinit*, *rvinit*, and *rwinit*.

C.1.8 Running with Range Reference Atmosphere Input

A major feature, new in GRAM-99 and expanded in GRAM07, is the (optional) ability to use data (in the form of vertical profiles) from a set of RRAs, as an alternate to the usual GRAM climatology, at a set of RRA site locations. With this feature it is possible, for example, to simulate a flight profile that takes off from the location of one RRA site (e.g. Edwards AFB, using the Edwards RRA atmospheric data), to smoothly transition into an atmosphere characterized by the GRAM climatology, then smoothly transition into an atmosphere characterized by a different RRA site (e.g. White Sands, NM), to be used as the landing site in the simulation. Use of the RRA option is controlled by setting input parameters *rrapath*, *iurra*, *iyrrra*, *sitelim*, and *sitenear*.

C.1.9 Running with Auxiliary Profile Input

As an option, data read from an auxiliary profile may be used to replace data from the conventional (GUACA/MAP/etc.) climatology. This option is controlled by setting parameters *profile*, *sitenear*, and *sitefar* in the NAMELIST input file. Each line of the auxiliary profile input file consists of: (1) height, in km (height values greater than 6,000 km are interpreted as radius values, in km), (2) latitude, in degrees, (3) longitude, in degrees (east positive), (4) temperature, in K, (5) pressure, in N/m**2, (6) density, in kg/m**3, (7) eastward wind, in m/s, and (8) northward wind, in m/s. Heights are relative to the reference ellipsoid, except that values greater than 6,000 km are interpreted as radius values, rather than altitudes. Latitudes are planetocentric. Regular climatological values (GUACA/MAP data etc.) are used if temperature, pressure, and density data are all three input as zero in the auxiliary profile. Regular climatological values of wind components are used if BOTH wind components are zero in the auxiliary profile file. Note that RRA input option and auxiliary profile input option cannot be used simultaneously. A sample auxiliary profile file (named SABERProf.txt) is provided.

C.1.10 Compiling and Running on Other Platforms

The MSFC Natural Environments Group does not have adequate resources to provide program versions and installation setups for all possible user platforms. Hopefully, the guidance provided above, and in README0.txt, will be adequate to allow users to setup, compile, and run GRAM07 on whatever platform they desire to use. For questions on compiling or running GRAM07, see contact information below.

If you have any questions or problems, please contact:

C. G. (Jere) Justus
E-mail: Carl.G.Justus@nasa.gov
Phone: (256)-544-3260
Fax: (256)-544-5754
Mail Code EV44/Stanley Associates
NASA Marshall Space Flight Center
Huntsville, AL 35812

For procedural or policy questions, contact:

Fred Leslie
E-mail: Fred.W.Leslie@nasa.gov
Phone: (256)-544-1633
Fax: (256)-544-5754
Mail Code EV44
NASA Marshall Space Flight Center
Huntsville, AL 35812

Copies of the GRAM-95 and GRAM-99 reports (NASA Technical Memorandum 4715, "The NASA/MSFC Global Reference Atmospheric Model—1995 Version (GRAM-95)," August, 1995 and NASA/TM-1999-209630 "The NASA/MSFC Global Reference Atmospheric Model—1999 Version (GRAM-99)," May, 1999 can be accessed at the following internet addresses:

<http://ntrs.nasa.gov/archive/nasa/casi.ntrs.nasa.gov/19960001687_1996101687.pdf>

<http://ntrs.nasa.gov/archive/nasa/casi.ntrs.nasa.gov/19990107329_1999176587.pdf>

APPENDIX D—DESCRIPTION OF NAMELIST FORMAT INPUT FILE

Following is a sample NAMELIST format input file (NameRef.txt) for use by GRAM07. Note that some compilers use different formats for the beginning and ending lines of the file. This sample file contains values required to produce the reference output data (file OutputRef.txt). These input values are also the default values set, if none are provided. Only values that differ from these default values actually need to be input in the NAMELIST file. Definitions and discussion of GRAM07 input parameters that are the same as GRAM-99 input parameters are given in appendix D of NASA/TM-1999- 209630. The input parameters that are new to GRAM07 are:

profile	= path name for auxiliary profile data ('null' if none)
iyrrra	= 1 for 1983 RRAs or 2 for 2006 RRAs
s10	= EUV index (26-34 nm) scaled to F10 units (0.0 → s10=f10)
s10b	= EUV 81-day center-averaged index (0.0 → s10b = f10b)
xm10	= MG2 index scaled to F10 units (0.0 → xm10 = f10)
xm10b	= MG2 81-day center-averaged index (0.0 → xm10b = f10b)
itherm	= 1 for MET (Jacchia), 2 for MSIS, or 3 for JB2006 thermosphere

D.1 Sample NAMELIST File

```
$namein
 atmpath = 'D:\EarthGRAM2007\PC_IOfiles\atmosdat.txt'
 guapath = 'D:\EarthGRAM2007\GUACAdata'
 trapath = 'null'
 prtpath = 'output.txt'
 nprpath = 'special.txt'
 conpath = 'species.txt'
 rndpath = 'null'
 rrapath = 'D:\EarthGRAM2007\RRAdata'
 profile = 'null'
 h1      = 140.
 phi1    = 0.45
 thet1   = –164.53
 f10     = 230.
 f10b    = 230.
 ap      = 20.3
 s10     = 0.
 s10b    = 0.
 xm10    = 0.
 xm10b   = 0.
 mn      = 1
```

```
 ida       = 1
 iyr       = 2007
 ihro      = 0
 mino      = 0
 seco      = 0.0
 dphi      = 0.4
 dthet     = 1.2
 dhgt      = –2.0
 nmax      = 71
 delt      = 60.0
 iopt      = 0
 iopp      = 17
 iu0       = 0
 iup       = 6
 ius       = 3
 iuc       = 4
 iug       = 22
 iguayr    = 1
 iopr      = 1
 nr1       = 1234
 iun       = 0
 rpscale   = 1.0
 iurra     = 0
 iyrrra    = 1
 sitelim   = 2.5
 sitenear  = 0.5
 initpert  = 0
 rpinit    = 0.
 Rdinit    = 0.
 Rtinit    = 0.
 Ruinit    = 0.
 Rvinit    = 0.
 Rwinit    = 0.
 Patchy    = 0.
 Itherm    = 1
$End
```

Parameter Descriptions:

atmpath = path name for "atmosdat" atmospheric data file
guapath = path name for GUACA or GGUAS files
trapath = path name for trajectory input file ('null' if none)
prtpath = path name for standard formatted output file ('null' if none)
nprpath = path name for the "special" format output file ('null' if none)
conpath = path name for species concentration output file ('null' if none)
rndpath = path name for file containing more random number seeds (optional)

rrapath = DIRECTORY for Range Reference Atmosphere data
profile = path name for auxiliary profile data ('null' if none)
h1 = initial height (km). Heights > 6,000 km are interpreted as radius.
phi1 = initial latitude (degrees, N positive)
thet1 = initial longitude (degrees, E positive)
f10 = daily 10.7-cm flux
f10b = mean 10.7-cm flux
ap = geomagnetic index
s10 = EUV index (26–34 nm) scaled to F10 units (0.0 –> s10 = f10)
s10b = EUV 81-day center-averaged index (0.0 –> s10b = f10b)
xm10 = MG2 index scaled to F10 units (0.0 –> xm10 = f10)
xm10b = MG2 81-day center-averaged index (0.0 –> xm10b = f10b)
mn = month (1–12)
ida = day of month
iyr = 4-digit year, or 2-digit year: >56 = 19xx <57 = 20XX
ihro = initial UTC (Greenwich) time hour (0–23)
mino = initial UTC (Greenwich) time minutes (0–59)
seco = initial UTC (Greenwich) time seconds (0.0–60.0)
dphi = latitude increment (degrees, N positive)
dthet = longitude increment (degrees, E positive)
dhgt = height increment (km, upward positive). If radius input is used, dhgt is interpreted as a radius increment.
nmax = maximum number of positions (including initial one; 0 means read trajectory input file)
delt = time increment between positions (real seconds)
iopt = trajectory option (0 = no trajectory data; otherwise unit number for trajectory input file)
iopp = "special" output option (0 = no "special" output; otherwise unit number of "special" output file)
iu0 = unit number for screen output (normally 6 or 0)
iup = unit number for standard formatted output file (0 for none)
ius = unit number for atmosdat data
iuc = unit number for concentrations output (0 for none)
iug = unit for GUACA or GGUAS input data, 0-27km (0 for no GUACA or GGUAS data)
iguayr = Use: 1 for GUACA period of record, 2 for actual GUACA year (1985–1991), based on iyr from input above, 3 for binary data converted from ASCII GGUAS POR data (conversion done with GGUASRD program, provided)
iopr = random output option (1 = random output, 2 = none)
nr1 = first starting random number (1 to 9 * 10**8)
iun = unit number for more starting random numbers (0 for none)
rpscale = random perturbation scale; nominal = 1.0, max = 2.0, min = 0.1
iurra = unit number for RRA data (0 if none)
iyrrra = 1 for 1983 RRAs or 2 for 2006 RRAs
sitelim = lat-lon radius (deg) from RRA site, outside which RRA data are NOT used. Also

used, with a similar meaning, for auxiliary profile input. Note that RRA and auxiliary profile input cannot be used simultaneously.

sitenear = lat-lon radius (deg) from RRA site, inside which RRA data is used with full weight of 1 (smooth transition of weight factor from 1 to 0 between sitenear and sitelim). Also used, with a similar meaning, for auxiliary profile input.

initpert = Use 1 for user-selected initial perturbations or 0 (default) for GRAM-derived, random initial perturbation values

rpinit = initial pressure perturbation value (% of mean)

rdinit = initial density perturbation value (% of mean)

rtinit = initial temperature perturbation value (% of mean)

ruinit = initial eastward velocity perturbation (m/s)

rvinit = initial northward velocity perturbation (m/s)

rwinit = initial upward velocity perturbation (m/s)

patchy = not equal 0 for patchiness; 0 to suppress patchiness in perturbation model

itherm = 1 for MET (Jacchia), 2 for MSIS, or 3 for JB2006 thermosphere

To satisfy the perfect gas law for the initial perturbations, values of *rpinit*, *rdinit*, and *rtinit* should be selected such that

rpinit = rdinit + rtinit

(i.e., 10.0 = 15.0–5.0 in this example).

Users wishing to use forecast future values of the solar activity parameters (F10.7 and ap) are referred to Marshall Space Flight Center Solar Activity Site web page:

<http://sail.msfc.nasa.gov/nse/solar.html>

APPENDIX E—SAMPLE OUTPUT OF GLOBAL REFERENCE ATMOSPHERIC MODEL 07

E.1 Sample Standard Formatted Output Produced by Input File of Appendix D

```
   **** Earth Global Reference Atmospheric Model - 2007 (Earth-GRAM-07) ****
                     Version 1, Released October, 2007
MM/DD/YYYY =  1/ 1/2007  HH:MM:SS(UTC) =  0: 0:  .0  Julian Day = 2454101.500
F10.7 =  230.00          Mean F10.7 =  230.00        ap Index =  20.30
Max of   71 positions, generated automatically.
Global Upper Air Climatic Atlas Data
 Path = D:\EarthGRAM2007\GUACAdata\por\01\
Thermospheric conditions from MET  model
Random Option = 1      1st Random No. =     1234    Random Scale Factor = 1.00
Patchy Turbulence Option = Off

Mean-76 and Total-76 are percent deviations from 1976 US Standard Atmosphere.
Other deviations in percent are with respect to mean values.  RH is relative
humidity in percent.  Zeroes for H2O indicate no estimate available.
E-W wind positive toward East; N-S wind positive toward North.

 Height/   GcLat    Long.                     Tempera-              Vert.
 Radius    GdLat   [E+W-] Pressure   Density/  ture/    E-W    N-S   Wind
  (km)     (deg)    (deg) /Vap.Pr.   Vap.Dens. Dewpt.  Wind   Wind   (m/s)
Time_sec   /RRA   /Weight (Nt/m**2)  (kg/m**3)   (K)   (m/s)  (m/s)  RH(%)
-------- ------- -------- --------- ---------- ------ ------ ------ ------ ----
 140.000    .450 -164.530 9.964E-04  4.406E-09  690.2   20.4     .3   .000 Mean
6518.136    .453            38.34%     14.99%  23.34%                      M-76
      .0    GRM    .0000      .08%      3.89%  -6.99%   84.0   -8.8        ranS
                            2.90%      6.19%  12.56%   45.0   45.0        sigS
                            1.94%      4.32%  -1.39%  -12.9   -6.6        ranL
                           12.16%      3.69%   7.44%   52.3   52.3        sigL
                            2.02%      8.20%  -8.38%   71.1  -15.4  -3.46 ranT
                           12.50%      7.20%  14.60%   69.0   69.0   8.33 sigT
                          1.017E-03  4.767E-09  632.4   91.5  -15.1  -3.46 Tot.
                           41.14%     24.42%  13.00%                      T-76
                          0.000E+00  0.000E+00     .0                  .0% H2O
                          0.000E+00  0.000E+00     .0                  .0% sigH
-------- ------- -------- --------- ---------- ------ ------ ------ ------ ----
 138.000    .850 -163.330 1.085E-03  5.021E-09  662.0   17.5     .5   .000 Mean
6516.132    .856            36.07%     14.25%  21.94%                      M-76
    60.0    GRM    .0000     -.97%     -2.08%   2.11%   66.1   -5.1        ranS
                            3.05%      6.22%  13.17%   45.0   44.9        sigS
                            4.29%      4.27%    .01%  -22.0  -15.9        ranL
                           12.84%      3.77%   7.94%   52.8   52.7        sigL
                            3.32%      2.19%   2.13%   44.1  -21.0   9.14 ranT
                           13.20%      7.27%  15.37%   69.4   69.3   8.16 sigT
                          1.121E-03  5.131E-09  676.1   61.5  -20.5   9.14 Tot.
                           40.59%     16.75%  24.54%                      T-76
                          0.000E+00  0.000E+00     .0                  .0% H2O
                          0.000E+00  0.000E+00     .0                  .0% sigH
-------- ------- -------- --------- ---------- ------ ------ ------ ------ ----
 136.000   1.250 -162.130 1.186E-03  5.764E-09  633.2   14.0     .6   .000 Mean
6514.127   1.258            33.84%     13.59%  20.49%                      M-76
   120.0    GRM    .0000    -1.27%     -3.16%   3.70%   69.5  -14.6        ranS
```

			3.18%	6.25%	13.74%	45.0	44.9		sigS
			6.75%	4.13%	1.57%	-30.8	-25.0		ranL
			13.49%	3.85%	8.42%	53.2	53.1		sigL
			5.48%	.97%	5.28%	38.7	-39.6	9.58	ranT
			13.86%	7.35%	16.11%	69.7	69.5	7.99	sigT
			1.251E-03	5.819E-09	666.6	52.7	-39.0	9.58	Tot.
			41.17%	14.69%	26.84%				T-76
			0.000E+00	0.000E+00	.0			.0%	H2O
			0.000E+00	0.000E+00	.0			.0%	sigH
--------	-------	--------	---------	----------	------	------	------	------	----
134.000	1.650	-160.930	1.303E-03	6.667E-09	603.8	10.1	.6	.000	Mean
6512.120	1.661		31.72%	13.07%	18.98%				M-76
180.0	GRM	.0000	-.71%	-3.85%	6.30%	64.4	48.7		ranS
			3.30%	6.29%	14.27%	45.0	44.8		sigS
			9.23%	3.87%	3.25%	-38.9	-33.5		ranL
			14.11%	3.94%	8.89%	53.7	53.5		sigL
			8.52%	.03%	9.55%	25.5	15.2	9.50	ranT
			14.49%	7.42%	16.82%	70.0	69.8	7.82	sigT
			1.414E-03	6.669E-09	661.5	35.6	15.8	9.50	Tot.
			42.94%	13.10%	30.35%				T-76
			0.000E+00	0.000E+00	.0			.0%	H2O
			0.000E+00	0.000E+00	.0			.0%	sigH
--------	-------	--------	---------	----------	------	------	------	------	----
132.000	2.050	-159.730	1.438E-03	7.777E-09	573.9	5.7	.5	.000	Mean
6510.110	2.064		29.66%	12.64%	17.43%				M-76
240.0	GRM	.0000	.41%	-.81%	2.51%	30.7	54.8		ranS
			3.41%	6.32%	14.78%	45.0	44.8		sigS
			11.66%	3.52%	5.00%	-46.3	-41.4		ranL
			14.70%	4.02%	9.35%	54.1	53.9		sigL
			12.07%	2.71%	7.50%	-15.6	13.4	8.09	ranT
			15.09%	7.49%	17.49%	70.4	70.1	7.65	sigT
			1.612E-03	7.988E-09	617.0	-9.9	13.9	8.09	Tot.
			45.30%	15.69%	26.24%				T-76
			0.000E+00	0.000E+00	.0			.0%	H2O
			0.000E+00	0.000E+00	.0			.0%	sigH
--------	-------	--------	---------	----------	------	------	------	------	----
130.000	2.450	-158.530	1.597E-03	9.158E-09	543.6	1.0	.4	.000	Mean
6508.098	2.466		27.70%	12.33%	15.85%				M-76
300.0	GRM	.0000	3.75%	-3.13%	14.46%	53.2	54.5		ranS
			3.52%	6.35%	15.26%	45.0	44.8		sigS
			13.96%	3.08%	6.75%	-52.7	-48.4		ranL
			15.27%	4.11%	9.81%	54.5	54.2		sigL
			17.70%	-.06%	21.21%	.4	6.0	7.44	ranT
			15.67%	7.56%	18.14%	70.7	70.3	7.48	sigT
			1.880E-03	9.153E-09	659.0	1.4	6.4	7.44	Tot.
			50.30%	12.27%	40.43%				T-76
			0.000E+00	0.000E+00	.0			.0%	H2O
			0.000E+00	0.000E+00	.0			.0%	sigH
--------	-------	--------	---------	----------	------	------	------	------	----
128.000	2.850	-157.330	1.785E-03	1.090E-08	513.1	-4.0	.3	.000	Mean
6506.084	2.869		25.89%	12.16%	14.26%				M-76
360.0	GRM	.0000	2.93%	-7.82%	23.05%	34.0	4.2		ranS
			3.63%	6.37%	15.72%	45.0	44.7		sigS
			16.04%	2.54%	8.47%	-58.1	-54.5		ranL
			15.82%	4.19%	10.26%	55.0	54.6		sigL
			18.98%	-5.28%	31.51%	-24.1	-50.3	6.81	ranT
			16.23%	7.63%	18.77%	71.0	70.6	7.31	sigT
			2.124E-03	1.032E-08	674.8	-28.1	-50.0	6.81	Tot.
			49.78%	6.24%	50.27%				T-76
			0.000E+00	0.000E+00	.0			.0%	H2O
			0.000E+00	0.000E+00	.0			.0%	sigH
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126.000	3.250	-156.130	2.010E-03	1.312E-08	482.3	-9.2	.1	.000	Mean
6504.068	3.271		24.13%	12.03%	12.68%				M-76
420.0	GRM	.0000	2.74%	-12.59%	33.38%	85.0	27.3		ranS
			3.75%	6.40%	16.15%	45.0	44.7		sigS
			17.85%	1.93%	10.09%	-62.2	-59.4		ranL
			16.35%	4.27%	10.71%	55.4	55.0		sigL
			20.59%	-10.66%	43.47%	22.8	-32.0	3.64	ranT
			16.77%	7.70%	19.38%	71.4	70.9	7.14	sigT
			2.424E-03	1.172E-08	692.0	13.7	-31.9	3.64	Tot.
			49.69%	.09%	61.66%				T-76
			0.000E+00	0.000E+00	.0			.0%	H2O
			0.000E+00	0.000E+00	.0			.0%	sigH
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124.000	3.650	-154.930	2.283E-03	1.599E-08	451.5	-14.2	.0	.000	Mean
6502.050	3.674		22.58%	12.04%	11.15%				M-76
480.0	GRM	.0000	-.11%	.60%	-1.57%	34.7	-6.5		ranS
			3.87%	6.43%	16.56%	44.9	44.6		sigS
			19.32%	1.26%	11.57%	-65.0	-63.1		ranL
			16.86%	4.36%	11.15%	55.8	55.4		sigL
			19.21%	1.86%	10.00%	-30.3	-69.6	3.19	ranT
			17.30%	7.77%	19.97%	71.7	71.2	6.97	sigT
			2.722E-03	1.629E-08	496.7	-44.5	-69.6	3.19	Tot.
			46.13%	14.13%	22.27%				T-76
			0.000E+00	0.000E+00	.0			.0%	H2O
			0.000E+00	0.000E+00	.0			.0%	sigH
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122.000	4.050	-153.730	2.619E-03	1.977E-08	421.0	-19.0	-.2	.000	Mean
6500.030	4.077		21.08%	11.95%	9.75%				M-76
540.0	GRM	.0000	.09%	-3.16%	7.26%	56.5	-33.8		ranS
			3.98%	6.45%	16.96%	44.9	44.6		sigS
			20.40%	.54%	12.86%	-66.5	-65.4		ranL
			17.35%	4.44%	11.59%	56.3	55.8		sigL
			20.49%	-2.62%	20.12%	-10.0	-99.2	-.87	ranT
			17.81%	7.83%	20.54%	72.0	71.4	6.80	sigT
			3.156E-03	1.926E-08	505.7	-28.9	-99.4	-.87	Tot.
			45.89%	9.02%	31.84%				T-76
			0.000E+00	0.000E+00	.0			.0%	H2O
			0.000E+00	0.000E+00	.0			.0%	sigH
--------	-------	--------	---------	----------	------	------	------	------	----
120.000	4.450	-152.530	3.038E-03	2.481E-08	391.1	-23.3	-.3	.000	Mean
6498.008	4.479		19.68%	11.65%	8.65%				M-76
600.0	GRM	.0000	3.74%	-9.04%	28.91%	12.5	23.5		ranS
			4.09%	6.48%	17.34%	44.8	44.5		sigS
			21.06%	-.22%	13.91%	-66.5	-66.5		ranL
			17.84%	4.52%	12.03%	56.7	56.2		sigL
			24.80%	-9.26%	42.83%	-54.0	-43.0	5.80	ranT
			18.30%	7.90%	21.10%	72.3	71.7	6.63	sigT
			3.791E-03	2.251E-08	558.6	-77.3	-43.2	5.80	Tot.
			49.36%	1.31%	55.18%				T-76
			0.000E+00	0.000E+00	.0			.0%	H2O
			0.000E+00	0.000E+00	.0			.0%	sigH
--------	-------	--------	---------	----------	------	------	------	------	----
118.000	4.850	-151.330	3.558E-03	3.154E-08	362.3	-26.5	-.3	.000	Mean
6495.983	4.882		18.06%	10.81%	7.82%				M-76
660.0	GRM	.0000	4.45%	-12.12%	32.96%	47.7	73.4		ranS
			3.98%	7.11%	16.20%	44.8	44.5		sigS
			20.15%	-1.09%	13.41%	-65.2	-66.1		ranL
			17.34%	5.04%	11.41%	57.1	56.7		sigL
			24.60%	-13.21%	46.37%	-17.5	7.3	-1.82	ranT
			17.79%	8.71%	19.81%	72.5	72.0	6.49	sigT

			4.434E-03	2.738E-08	530.3	-44.1	6.9	-1.82	Tot.
			47.10%	-3.83%	57.82%				T-76
			1.135E-09	7.361E-15	186.1			.0%	H2O
			4.084E-10	2.650E-15	.0			.0%	sigH
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116.000	5.250	-150.130	4.207E-03	4.062E-08	334.3	-28.1	-.5	.000	Mean
6493.957	5.285		15.82%	9.16%	7.14%				M-76
720.0	GRM	.0000	4.81%	-6.91%	21.77%	51.4	8.6		ranS
			3.86%	7.67%	15.00%	44.7	44.4		sigS
			18.85%	-2.08%	12.66%	-62.6	-64.5		ranL
			16.83%	5.52%	10.71%	57.4	57.1		sigL
			23.66%	-8.99%	34.44%	-11.1	-55.9	2.16	ranT
			17.27%	9.45%	18.43%	72.8	72.3	6.36	sigT
			5.202E-03	3.697E-08	449.4	-39.3	-56.4	2.16	Tot.
			43.22%	-.65%	44.04%				T-76
			1.450E-09	1.014E-14	180.0			.0%	H2O
			5.221E-10	3.652E-15	.0			.0%	sigH
--------	-------	--------	---------	----------	------	------	------	------	----
114.000	5.650	-148.930	5.037E-03	5.320E-08	307.3	-28.0	-.6	.000	Mean
6491.929	5.687		13.26%	6.92%	6.70%				M-76
780.0	GRM	.0000	1.19%	-11.20%	21.22%	37.9	14.0		ranS
			3.75%	8.25%	13.82%	44.6	44.4		sigS
			17.27%	-3.19%	11.77%	-58.7	-61.6		ranL
			16.34%	6.02%	10.02%	57.8	57.5		sigL
			18.46%	-14.38%	32.99%	-20.8	-47.6	-2.25	ranT
			16.77%	10.21%	17.07%	73.0	72.6	6.22	sigT
			5.967E-03	4.555E-08	408.7	-48.7	-48.2	-2.25	Tot.
			34.16%	-8.46%	41.90%				T-76
			1.867E-09	1.413E-14	173.2			.0%	H2O
			6.723E-10	5.088E-15	.0			.0%	sigH
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112.000	6.050	-147.730	6.134E-03	7.114E-08	281.5	-26.0	-.9	.000	Mean
6489.898	6.090		10.43%	4.04%	6.62%				M-76
840.0	GRM	.0000	-1.93%	-15.04%	20.41%	7.5	116.0		ranS
			3.64%	8.82%	12.69%	44.5	44.3		sigS
			15.45%	-4.38%	10.78%	-53.6	-57.4		ranL
			15.88%	6.53%	9.33%	58.2	57.9		sigL
			13.52%	-19.42%	31.18%	-46.0	58.6	.23	ranT
			16.29%	10.98%	15.75%	73.3	72.9	6.09	sigT
			6.963E-03	5.733E-08	369.2	-72.0	57.7	.23	Tot.
			25.36%	-16.16%	39.86%				T-76
			2.433E-09	1.999E-14	166.0			.0%	H2O
			8.759E-10	7.195E-15	.0			.0%	sigH
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110.000	6.450	-146.530	7.636E-03	9.790E-08	256.3	-22.7	-1.3	.000	Mean
6487.866	6.492		7.49%	.85%	6.80%				M-76
900.0	GRM	.0000	-1.26%	-1.69%	.60%	14.5	71.7		ranS
			3.53%	9.36%	11.46%	44.4	44.3		sigS
			13.44%	-5.60%	9.62%	-47.5	-52.1		ranL
			15.40%	7.02%	8.55%	58.5	58.3		sigL
			12.17%	-7.29%	10.21%	-32.9	19.5	1.51	ranT
			15.80%	11.70%	14.30%	73.5	73.3	5.95	sigT
			8.566E-03	9.076E-08	282.5	-55.6	18.3	1.51	Tot.
			20.58%	-6.51%	17.71%				T-76
			3.243E-09	2.906E-14	158.2			.0%	H2O
			1.167E-09	1.046E-14	.0			.0%	sigH
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108.000	6.850	-145.330	9.757E-03	1.367E-07	236.1	-18.0	-1.8	.000	Mean
6485.832	6.895		4.70%	-1.05%	5.73%				M-76
960.0	GRM	.0000	-1.47%	-9.93%	10.46%	34.2	32.8		ranS

			3.42%	9.91%	10.40%	44.3	44.2		sigS
			11.28%	-6.85%	8.54%	-40.5	-45.9		ranL
			14.91%	7.54%	7.87%	58.8	58.8		sigL
			9.81%	-16.78%	19.00%	-6.2	-13.1	.98	ranT
			15.29%	12.45%	13.05%	73.7	73.6	5.81	sigT
			1.071E-02	1.138E-07	280.9	-24.2	-14.9	.98	Tot.
			14.98%	-17.65%	25.82%				T-76
			4.507E-09	4.357E-14	151.3			.0%	H2O
			1.623E-09	1.569E-14	.0			.0%	sigH
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106.000	7.250	-144.130	1.281E-02	1.955E-07	218.1	-12.7	-2.4	.000	Mean
6483.795	7.298		2.84%	.09%	2.46%				M-76
1020.0	GRM	.0000	-4.52%	-5.08%	.60%	42.3	-38.3		ranS
			3.30%	10.42%	9.25%	44.2	44.2		sigS
			9.05%	-8.05%	7.36%	-32.7	-38.8		ranL
			14.40%	8.04%	7.10%	59.2	59.2		sigL
			4.53%	-13.13%	7.96%	9.6	-77.1	.72	ranT
			14.77%	13.16%	11.66%	73.8	73.9	5.68	sigT
			1.339E-02	1.699E-07	235.5	-3.1	-79.5	.72	Tot.
			7.49%	-13.05%	10.61%				T-76
			6.438E-09	6.690E-14	144.7			.0%	H2O
			2.318E-09	2.408E-14	.0			.0%	sigH
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104.000	7.650	-142.930	1.728E-02	2.839E-07	204.1	-8.1	-3.2	.000	Mean
6481.756	7.700		2.37%	2.56%	-.59%				M-76
1080.0	GRM	.0000	-4.37%	-12.18%	7.81%	37.2	-25.0		ranS
			3.19%	10.95%	8.14%	44.0	44.2		sigS
			6.82%	-9.21%	6.22%	-24.4	-31.0		ranL
			13.89%	8.57%	6.33%	59.5	59.7		sigL
			2.45%	-21.39%	14.02%	12.8	-56.0	1.39	ranT
			14.25%	13.90%	10.31%	74.0	74.2	5.54	sigT
			1.770E-02	2.232E-07	232.7	4.7	-59.2	1.39	Tot.
			4.88%	-19.38%	13.35%				T-76
			9.400E-09	1.037E-13	139.2			.0%	H2O
			3.382E-09	3.730E-14	.0			.0%	sigH
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102.000	8.050	-141.730	2.385E-02	4.138E-07	194.5	-4.8	-4.1	.000	Mean
6479.716	8.103		3.12%	5.26%	-2.51%				M-76
1140.0	GRM	.0000	-3.34%	-18.90%	15.57%	15.8	65.9		ranS
			3.07%	11.49%	7.08%	43.9	44.1		sigS
			4.65%	-10.30%	5.15%	-15.7	-22.7		ranL
			13.39%	9.12%	5.58%	59.8	60.1		sigL
			1.31%	-29.21%	20.72%	.1	43.2	-4.07	ranT
			13.73%	14.67%	9.02%	74.2	74.5	5.40	sigT
			2.416E-02	2.930E-07	234.8	-4.7	39.1	-4.07	Tot.
			4.47%	-25.49%	17.69%				T-76
			1.398E-08	1.606E-13	135.4			.0%	H2O
			5.014E-09	5.762E-14	.1			.0%	sigH
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100.000	8.450	-140.530	3.351E-02	6.094E-07	186.9	-2.7	-5.2	.000	Mean
6477.673	8.505		4.69%	8.75%	-4.19%				M-76
1200.0	GRM	.0000	-.71%	.14%	-.86%	5.0	34.9		ranS
			2.95%	12.00%	5.86%	43.7	44.0		sigS
			2.56%	-11.25%	4.02%	-6.8	-13.9		ranL
			12.87%	9.65%	4.68%	60.1	60.5		sigL
			1.85%	-11.10%	3.17%	-1.8	21.0	-9.79	ranT
			13.20%	15.40%	7.50%	74.3	74.8	5.26	sigT
			3.413E-02	5.418E-07	192.8	-4.5	15.8	-9.79	Tot.
			6.63%	-3.33%	-1.15%				T-76

			2.135E-08	2.537E-13	132.2			.0%	H2O
			7.570E-09	8.994E-14	.3			.0%	sigH
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98.000	8.850	-139.330	4.775E-02	8.875E-07	183.9	-2.1	-6.0	-.001	Mean
6475.628	8.908		6.08%	10.07%	-4.09%				M-76
1260.0	GRM	.0000	-1.07%	-2.36%	1.29%	32.5	-1.8		ranS
			3.05%	11.33%	5.99%	43.2	43.8		sigS
			.68%	-11.17%	3.52%	1.7	-5.1		ranL
			13.32%	9.46%	4.85%	60.9	61.7		sigL
			-.40%	-13.53%	4.81%	34.2	-6.8	-5.60	ranT
			13.66%	14.76%	7.70%	74.7	75.7	5.16	sigT
			4.756E-02	7.674E-07	192.7	32.1	-12.8	-5.60	Tot.
			5.66%	-4.82%	.52%				T-76
			3.519E-08	4.227E-13	131.1			.0%	H2O
			1.223E-08	1.469E-13	.6			.0%	sigH
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96.000	9.250	-138.130	6.841E-02	1.291E-06	182.1	-2.3	-6.5	-.001	Mean
6473.582	9.310		7.28%	11.07%	-3.81%				M-76
1320.0	GRM	.0000	-.65%	-.28%	-.37%	13.3	18.5		ranS
			3.17%	10.66%	6.11%	42.7	43.6		sigS
			-1.32%	-10.87%	2.88%	10.2	4.1		ranL
			13.80%	9.23%	5.02%	61.6	62.9		sigL
			-1.97%	-11.15%	2.51%	23.5	22.6	-1.79	ranT
			14.16%	14.10%	7.90%	75.0	76.5	5.06	sigT
			6.706E-02	1.147E-06	186.7	21.1	16.1	-1.79	Tot.
			5.16%	-1.32%	-1.39%				T-76
			5.763E-08	6.953E-13	131.9			.0%	H2O
			1.986E-08	2.396E-13	.8			.0%	sigH
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94.000	9.650	-136.930	9.907E-02	1.872E-06	182.6	-3.6	-6.8	-.001	Mean
6471.533	9.713		9.39%	12.09%	-2.74%				M-76
1380.0	GRM	.0000	-1.43%	1.46%	-2.89%	-34.9	-3.4		ranS
			3.29%	10.01%	6.24%	42.2	43.4		sigS
			-3.42%	-10.40%	2.14%	18.6	13.4		ranL
			14.33%	8.99%	5.20%	62.4	64.1		sigL
			-4.85%	-8.94%	-.75%	-16.3	10.0	-1.49	ranT
			14.71%	13.45%	8.12%	75.3	77.3	4.96	sigT
			9.427E-02	1.705E-06	181.2	-20.0	3.2	-1.49	Tot.
			4.09%	2.07%	-3.47%				T-76
			9.776E-08	1.171E-12	133.2			.0%	H2O
			3.358E-08	4.024E-13	.8			.0%	sigH
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92.000	10.050	-135.730	1.441E-01	2.695E-06	185.1	-5.5	-7.0	.003	Mean
6469.483	10.115		11.85%	12.64%	-.99%				M-76
1440.0	GRM	.0000	-.20%	-1.42%	1.22%	-35.2	29.2		ranS
			3.42%	9.38%	6.39%	41.6	43.1		sigS
			-5.59%	-9.78%	1.31%	26.7	22.7		ranL
			14.90%	8.73%	5.39%	63.0	65.3		sigL
			-5.79%	-11.20%	2.53%	-8.5	51.8	-3.28	ranT
			15.29%	12.81%	8.36%	75.6	78.3	4.85	sigT
			1.358E-01	2.393E-06	189.8	-14.0	44.8	-3.27	Tot.
			5.38%	.03%	1.51%				T-76
			1.713E-07	2.018E-12	134.8			.0%	H2O
			5.876E-08	6.924E-13	.9			.0%	sigH
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90.000	10.450	-134.530	2.082E-01	3.845E-06	188.0	-6.6	-6.7	.004	Mean
6467.430	10.518		13.38%	12.53%	.61%				M-76
1500.0	GRM	.0000	-3.66%	-10.72%	7.58%	-60.2	-4.5		ranS
			3.52%	8.74%	6.52%	40.9	43.3		sigS
			-7.72%	-9.01%	.41%	34.5	32.3		ranL

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                                15.36%      8.43%    5.58%   63.5   67.2          sigL
                               -11.38%    -19.73%    7.99%  -25.7   27.8    -.38 ranT
                                15.76%     12.14%    8.58%   75.5   80.0    4.75 sigT
                               1.845E-01  3.086E-06  203.0  -32.3   21.1    -.38 Tot.
                                  .47%     -9.67%    8.65%                        T-76
                               2.990E-07  3.445E-12  136.4                   .0% H2O
                               1.024E-07  1.180E-12     .9                   .0% sigH
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  88.000  10.850 -133.330 2.957E-01  5.367E-06  191.5   -3.8   -5.1    .003 Mean
6465.376  10.920            12.97%     10.09%    2.48%                        M-76
   1560.0    GRM    .0000   -2.59%     -6.77%    4.18%    6.1    5.8          ranS
                             2.93%      7.20%    5.51%   35.1   35.7          sigS
                            -7.94%     -7.23%    -.23%   36.6   34.4          ranL
                            12.78%      7.19%    4.78%   56.0   56.9          sigL
                           -10.53%    -14.00%    3.95%   42.6   40.2    5.90 ranT
                            13.11%     10.18%    7.29%   66.1   67.2    4.49 sigT
                          2.645E-01  4.616E-06  199.1   38.9   35.1    5.90 Tot.
                             1.08%     -5.33%    6.53%                        T-76
                          5.033E-07  5.695E-12  138.0                    .0% H2O
                          1.724E-07  1.951E-12     .9                    .0% sigH
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  86.000  11.250 -132.130 4.174E-01  7.449E-06  195.0    -.9   -3.6    .002 Mean
6463.319  11.323            11.80%      7.06%    4.36%                        M-76
   1620.0    GRM    .0000    -.06%      1.06%   -1.12%   26.3  -63.7          ranS
                             2.20%      5.36%    4.31%   28.9   26.1          sigS
                            -6.99%     -5.16%    -.63%   35.7   30.7          ranL
                             9.59%      5.55%    3.79%   47.4   42.8          sigL
                            -7.05%     -4.10%   -1.75%   61.9  -33.0   -2.96 ranT
                             9.84%      7.71%    5.74%   55.5   50.2    4.22 sigT
                          3.880E-01  7.144E-06  191.6   61.0  -36.6   -2.96 Tot.
                             3.91%      2.67%    2.54%                        T-76
                          8.422E-07  9.357E-12  139.7                    .0% H2O
                          2.885E-07  3.206E-12    1.0                    .0% sigH
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  84.000  11.650 -130.930 5.844E-01  1.027E-05  198.2    1.6   -2.9    .001 Mean
6461.261  11.725            10.04%      5.91%    3.86%                        M-76
   1680.0    GRM    .0000    -.03%     -1.14%    1.11%   22.1  -31.0          ranS
                             1.64%      4.00%    3.44%   24.3   18.5          sigS
                            -5.90%     -3.63%    -.83%   34.5   25.5          ranL
                             7.14%      4.29%    3.06%   40.9   31.2          sigL
                            -5.93%     -4.77%     .28%   56.5   -5.5   -4.32 ranT
                             7.33%      5.86%    4.61%   47.6   36.3    3.93 sigT
                          5.497E-01  9.776E-06  198.8   58.1   -8.4   -4.32 Tot.
                             3.52%       .85%    4.15%                        T-76
                          1.413E-06  1.544E-11  141.4                    .0% H2O
                          4.840E-07  5.292E-12    1.0                    .0% sigH
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  82.000  12.050 -129.730 8.121E-01  1.407E-05  201.0    4.1   -3.0    .001 Mean
6459.201  12.128             8.26%      4.84%    3.23%                        M-76
   1740.0    GRM    .0000     .24%       .25%    -.01%   14.9  -33.5          ranS
                             1.45%      3.57%    3.14%   21.8   16.0          sigS
                            -5.76%     -3.00%   -1.05%   34.7   25.0          ranL
                             6.34%      3.97%    2.83%   37.7   27.6          sigL
                            -5.52%     -2.75%   -1.06%   49.6   -8.5   -5.34 ranT
                             6.51%      5.34%    4.23%   43.5   31.9    3.62 sigT
                          7.672E-01  1.368E-05  198.9   53.7  -11.5   -5.34 Tot.
                             2.28%      1.96%    2.14%                        T-76
                          2.380E-06  2.565E-11  143.1                    .0% H2O
                          8.148E-07  8.783E-12    1.0                    .0% sigH
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  80.000  12.450 -128.530 1.123E+00  1.920E-05  203.8     7.1    -3.2    .001 Mean
6457.139  12.530             6.74%      4.04%    2.58%                         M-76
   1800.0    GRM    .0000     .87%      1.93%   -1.06%  -24.7  -24.6           ranS
                             1.25%      3.12%    2.82%   19.2   13.2           sigS
                            -5.33%     -2.38%   -1.17%   33.7   23.0           ranL
                             5.44%      3.60%    2.58%   34.1   23.5           sigL
                            -4.46%      -.45%   -2.23%    9.0   -1.7   -4.54 ranT
                             5.58%      4.76%    3.82%   39.1   26.9    3.30 sigT
                          1.073E+00  1.912E-05  199.2    16.1   -4.8   -4.54 Tot.
                             1.98%      3.57%     .29%                         T-76
                          3.594E-06  3.821E-11  144.6                    .0% H2O
                          1.084E-06  1.153E-11     .9                    .0% sigH
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  78.000  12.850 -127.330 1.549E+00  2.618E-05  206.0    13.6    -1.1    .000 Mean
6455.074  12.933             5.54%      3.73%    1.72%                         M-76
   1860.0    GRM    .0000    1.10%      4.17%   -3.06%  -35.7  -13.2           ranS
                             1.24%      3.00%    2.79%   18.2   12.3           sigS
                            -5.62%     -2.01%   -1.43%   34.9   23.5           ranL
                             5.40%      3.59%    2.58%   33.4   22.6           sigL
                            -4.51%      2.15%   -4.50%    -.8   10.3     .91 ranT
                             5.54%      4.68%    3.80%   38.0   25.8    2.98 sigT
                          1.479E+00  2.674E-05  196.8    12.7    9.3     .91 Tot.
                              .78%      5.96%   -2.85%                         T-76
                          4.243E-06  4.462E-11  145.0                    .0% H2O
                          1.494E-06  1.571E-11    1.1                    .0% sigH
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  76.000  13.250 -126.130 2.128E+00  3.559E-05  208.3    20.1      .8    .000 Mean
6453.008  13.335             4.68%      3.72%     .89%                         M-76
   1920.0    GRM    .0000    3.04%      6.17%   -3.14%  -31.9   -5.3           ranS
                             1.23%      2.88%    2.76%   17.2   11.5           sigS
                            -5.85%     -1.65%   -1.68%   35.5   23.6           ranL
                             5.37%      3.57%    2.59%   32.6   21.7           sigL
                            -2.81%      4.52%   -4.82%    3.6   18.4    -.21 ranT
                             5.51%      4.59%    3.78%   36.9   24.6    2.67 sigT
                          2.069E+00  3.720E-05  198.2    23.7   19.2    -.21 Tot.
                             1.74%      8.41%   -3.97%                         T-76
                          6.408E-06  6.666E-11  146.4                    .0% H2O
                          2.053E-06  2.136E-11    1.1                    .0% sigH
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  74.000  13.650 -124.930 2.919E+00  4.805E-05  211.6    25.4     1.5    .000 Mean
6450.940  13.737             4.20%      3.58%     .58%                         M-76
   1980.0    GRM    .0000    2.13%      1.50%     .63%  -31.7    4.2           ranS
                             1.18%      2.72%    2.57%   17.0   10.8           sigS
                            -5.77%     -1.27%   -1.84%   35.1   22.2           ranL
                             5.13%      3.49%    2.53%   31.2   19.7           sigL
                            -3.63%       .23%   -1.20%    3.4   26.4    1.61 ranT
                             5.26%      4.43%    3.61%   35.5   22.4    2.39 sigT
                          2.813E+00  4.816E-05  209.0    28.8   27.9    1.61 Tot.
                              .42%      3.82%    -.63%                         T-76
                          9.631E-06  9.864E-11  148.2                    .0% H2O
                          2.816E-06  2.884E-11     .9                    .0% sigH
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  72.000  14.050 -123.730 3.983E+00  6.428E-05  215.9    29.7     1.1    .000 Mean
6448.871  14.140             3.83%      3.06%     .75%                         M-76
   2040.0    GRM    .0000    2.06%      2.99%    -.93%  -20.8    2.8           ranS
                             1.06%      2.51%    2.23%   17.5    9.7           sigS
                            -5.31%      -.89%   -1.86%   33.8   18.8           ranL
                             4.61%      3.33%    2.39%   29.4   16.3           sigL
                            -3.25%      2.11%   -2.79%   13.0   21.6    1.91 ranT
                             4.73%      4.17%    3.26%   34.2   19.0    2.15 sigT
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			3.854E+00	6.564E-05	209.8	42.7	22.7	1.91	Tot.
			.46%	5.23%	-2.06%				T-76
			1.735E-05	1.742E-10	151.2			.0%	H2O
			4.812E-06	4.831E-11	.7			.0%	sigH
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70.000	14.450	-122.530	5.404E+00	8.555E-05	220.1	34.1	.8	.000	Mean
6446.799	14.542		3.50%	3.28%	.24%				M-76
2100.0	GRM	.0000	1.16%	-1.30%	2.47%	-6.3	-7.0		ranS
			.92%	2.29%	1.88%	17.8	8.0		sigS
			-4.70%	-.54%	-1.79%	32.2	14.5		ranL
			4.02%	3.13%	2.19%	27.6	12.4		sigL
			-3.54%	-1.85%	.68%	25.9	7.5	-.26	ranT
			4.13%	3.88%	2.88%	32.8	14.7	1.91	sigT
			5.213E+00	8.397E-05	221.6	59.9	8.3	-.26	Tot.
			-.16%	1.37%	.92%				T-76
			3.056E-05	3.008E-10	154.1			.0%	H2O
			7.602E-06	7.484E-11	.6			.0%	sigH
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68.000	14.850	-121.330	7.281E+00	1.121E-04	226.4	35.1	.6	.000	Mean
6444.726	14.945		3.23%	2.67%	.58%				M-76
2160.0	GRM	.0000	.76%	.15%	.62%	6.5	-10.7		ranS
			.90%	2.31%	1.72%	17.3	8.5		sigS
			-4.65%	-.28%	-1.87%	29.4	14.6		ranL
			3.94%	3.26%	2.19%	25.0	12.3		sigL
			-3.88%	-.13%	-1.26%	35.9	3.9	.61	ranT
			4.04%	4.00%	2.79%	30.4	15.0	1.76	sigT
			6.998E+00	1.119E-04	223.5	71.0	4.5	.61	Tot.
			-.78%	2.53%	-.68%				T-76
			4.872E-05	4.663E-10	157.6			.0%	H2O
			9.194E-06	8.800E-11	.3			.0%	sigH
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66.000	15.250	-120.130	9.730E+00	1.458E-04	232.5	36.3	.4	.000	Mean
6442.651	15.347		2.84%	2.00%	.86%				M-76
2220.0	GRM	.0000	-.30%	.32%	-.63%	-.3	-12.1		ranS
			.88%	2.42%	1.60%	16.5	9.1		sigS
			-4.52%	-.01%	-1.94%	26.4	14.5		ranL
			3.83%	3.27%	2.16%	22.3	12.3		sigL
			-4.83%	.31%	-2.57%	26.0	2.5	-1.14	ranT
			3.93%	4.07%	2.69%	27.8	15.3	1.61	sigT
			9.260E+00	1.463E-04	226.6	62.3	2.9	-1.14	Tot.
			-2.13%	2.32%	-1.73%				T-76
			7.716E-05	7.190E-10	161.0			.0%	H2O
			1.106E-05	1.031E-10	.2			.0%	sigH
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64.000	15.650	-118.930	1.292E+01	1.890E-04	238.2	36.3	.4	.001	Mean
6440.574	15.749		2.49%	1.60%	.90%				M-76
2280.0	GRM	.0000	-1.01%	-3.56%	2.55%	-21.0	-3.2		ranS
			.92%	2.64%	1.62%	16.4	9.5		sigS
			-4.71%	.23%	-1.92%	23.9	13.8		ranL
			3.99%	3.26%	2.00%	20.2	11.7		sigL
			-5.72%	-3.32%	.63%	2.9	10.6	.88	ranT
			4.10%	4.20%	2.58%	26.0	15.0	1.55	sigT
			1.218E+01	1.827E-04	239.7	39.2	11.0	.88	Tot.
			-3.37%	-1.78%	1.53%				T-76
			1.114E-04	1.013E-09	163.8			.0%	H2O
			1.659E-05	1.509E-10	.1			.0%	sigH
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62.000	16.050	-117.730	1.707E+01	2.444E-04	243.3	35.1	.5	.001	Mean
6438.495	16.152		2.28%	1.53%	.74%				M-76
2340.0	GRM	.0000	-2.04%	-5.32%	3.28%	-3.2	2.7		ranS

			1.01%	2.96%	1.63%	17.0	9.5		sigS
			-5.19%	.46%	-1.85%	22.0	12.3		ranL
			4.42%	3.27%	1.80%	18.7	10.5		sigL
			-7.23%	-4.87%	1.43%	18.8	15.0	-.67	ranT
			4.54%	4.41%	2.43%	25.3	14.2	1.58	sigT
			1.584E+01	2.325E-04	246.8	53.9	15.5	-.67	Tot.
			-5.12%	-3.42%	2.18%				T-76
			1.583E-04	1.410E-09	166.3			.0%	H2O
			2.530E-05	2.253E-10	.1			.0%	sigH
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60.000	16.450	-116.530	2.243E+01	3.144E-04	248.4	34.0	.6	.001	Mean
6436.415	16.554		2.13%	1.53%	.57%				M-76
2400.0	GRM	.0000	-1.08%	.15%	-1.23%	12.0	.2		ranS
			1.10%	3.27%	1.61%	17.4	9.4		sigS
			-5.60%	.65%	-1.72%	20.1	10.8		ranL
			4.81%	3.24%	1.59%	17.2	9.3		sigL
			-6.68%	.80%	-2.94%	32.1	11.0	1.55	ranT
			4.94%	4.61%	2.27%	24.4	13.2	1.61	sigT
			2.093E+01	3.169E-04	241.1	66.1	11.6	1.55	Tot.
			-4.70%	2.34%	-2.39%				T-76
			2.144E-04	1.870E-09	168.7			.0%	H2O
			3.383E-05	2.950E-10	.1			.0%	sigH
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58.000	16.850	-115.330	2.929E+01	4.026E-04	253.5	29.5	.2	.000	Mean
6434.332	16.956		1.96%	1.59%	.38%				M-76
2460.0	GRM	.0000	.32%	4.61%	-4.29%	18.4	-7.9		ranS
			1.06%	3.25%	1.60%	17.9	9.4		sigS
			-5.34%	.75%	-1.63%	19.1	9.9		ranL
			4.62%	2.97%	1.47%	16.4	8.6		sigL
			-5.02%	5.35%	-5.92%	37.4	2.0	2.95	ranT
			4.74%	4.40%	2.18%	24.3	12.7	1.53	sigT
			2.782E+01	4.241E-04	238.5	66.9	2.2	2.95	Tot.
			-3.16%	7.03%	-5.56%				T-76
			2.728E-04	2.332E-09	170.6			.0%	H2O
			3.807E-05	3.254E-10	.1			.0%	sigH
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56.000	17.250	-114.130	3.805E+01	5.129E-04	258.6	25.0	-.3	.000	Mean
6432.248	17.358		1.84%	1.67%	.22%				M-76
2520.0	GRM	.0000	1.57%	6.57%	-5.00%	-5.7	-14.2		ranS
			1.02%	3.21%	1.59%	18.5	9.3		sigS
			-5.07%	.80%	-1.52%	18.0	9.0		ranL
			4.43%	2.71%	1.35%	15.7	7.9		sigL
			-3.50%	7.37%	-6.53%	12.3	-5.2	-.53	ranT
			4.55%	4.20%	2.09%	24.3	12.2	1.46	sigT
			3.672E+01	5.507E-04	241.7	37.3	-5.4	-.53	Tot.
			-1.73%	9.17%	-6.32%				T-76
			3.456E-04	2.896E-09	172.6			.0%	H2O
			4.274E-05	3.581E-10	.1			.0%	sigH
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54.000	17.650	-112.930	4.920E+01	6.535E-04	262.4	21.0	-.5	.000	Mean
6430.162	17.761		1.78%	2.26%	-.42%				M-76
2580.0	GRM	.0000	.94%	.99%	-.05%	-1.6	4.0		ranS
			.98%	3.11%	1.57%	18.9	9.3		sigS
			-4.83%	.83%	-1.46%	17.5	8.5		ranL
			4.26%	2.53%	1.27%	15.4	7.5		sigL
			-3.89%	1.82%	-1.51%	16.0	12.5	-2.30	ranT
			4.37%	4.01%	2.02%	24.4	11.9	1.37	sigT
			4.728E+01	6.654E-04	258.5	37.0	12.0	-2.30	Tot.
			-2.19%	4.13%	-1.92%				T-76

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                              4.360E-04  3.600E-09  174.0                      .0% H2O
                              4.789E-05  3.954E-10     .1                      .0% sigH
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  52.000  18.050 -111.730 6.343E+01  8.341E-04  265.0   17.3    -.6   .000 Mean
6428.075  18.163              1.95%      3.53%  -1.50%                     M-76
  2640.0     GRM    .0000      .87%      2.78%  -1.92%  -15.4    4.5        ranS
                               .94%      2.96%   1.51%   19.1    9.2        sigS
                             -4.61%       .85%  -1.42%   17.6    8.5        ranL
                              4.08%      2.41%   1.23%   15.6    7.5        sigL
                             -3.74%      3.64%  -3.34%    2.2   13.0   -.69 ranT
                              4.19%      3.82%   1.95%   24.7   11.9   1.26 sigT
                            6.106E+01  8.645E-04  256.2   19.5   12.4   -.69 Tot.
                             -1.87%      7.30%  -4.79%                     T-76
                            5.611E-04  4.588E-09  175.1                    .0% H2O
                            5.379E-05  4.398E-10     .1                    .0% sigH
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  50.000  18.450 -110.530 8.158E+01  1.062E-03  267.7   13.5    -.6   .000 Mean
6425.986  18.565              2.26%      3.41%  -1.10%                     M-76
  2700.0     GRM    .0000     1.47%      4.45%  -2.98%    5.5   -8.8        ranS
                               .89%      2.80%   1.45%   19.3    9.1        sigS
                             -4.38%       .85%  -1.37%   17.8    8.4        ranL
                              3.90%      2.29%   1.19%   15.8    7.5        sigL
                             -2.91%      5.30%  -4.35%   23.3    -.4   -.71 ranT
                              4.00%      3.62%   1.87%   25.0   11.8   1.15 sigT
                            7.921E+01  1.118E-03  256.0   36.8   -1.0   -.71 Tot.
                              -.71%      8.89%  -5.41%                     T-76
                            6.986E-04  5.655E-09  175.9                    .0% H2O
                            5.267E-05  4.264E-10     .0                    .0% sigH
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  48.000  18.850 -109.330 1.048E+02  1.368E-03  266.8   13.6    -.7   .000 Mean
6423.895  18.967              2.41%      3.91%  -1.44%                     M-76
  2760.0     GRM    .0000     1.09%      1.84%   -.75%  -26.2   -6.5        ranS
                               .85%      2.70%   1.46%   18.7    8.5        sigS
                             -4.16%       .85%  -1.42%   17.7    8.0        ranL
                              3.71%      2.28%   1.23%   15.7    7.1        sigL
                             -3.07%      2.69%  -2.17%   -8.5    1.5    .27 ranT
                              3.81%      3.53%   1.91%   24.4   11.1   1.05 sigT
                            1.015E+02  1.405E-03  261.0    5.1     .8    .27 Tot.
                              -.74%      6.71%  -3.57%                     T-76
                            8.570E-04  6.961E-09  175.3                    .0% H2O
                            5.117E-05  4.156E-10     .0                    .0% sigH
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  46.000  19.250 -108.130 1.346E+02  1.764E-03  265.9   13.6    -.7   .000 Mean
6421.802  19.369              2.51%      2.90%   -.38%                     M-76
  2820.0     GRM    .0000      .93%      2.04%  -1.11%    5.2   -6.6        ranS
                               .81%      2.60%   1.47%   18.0    7.8        sigS
                             -3.94%       .83%  -1.46%   17.6    7.6        ranL
                              3.51%      2.26%   1.28%   15.6    6.8        sigL
                             -3.02%      2.87%  -2.58%   22.8    1.0    .22 ranT
                              3.61%      3.44%   1.95%   23.8   10.3    .94 sigT
                            1.306E+02  1.814E-03  259.1   36.4     .2    .22 Tot.
                              -.59%      5.85%  -2.95%                     T-76
                            1.086E-03  8.851E-09  174.9                    .0% H2O
                            7.047E-05  5.743E-10     .1                    .0% sigH
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  44.000  19.650 -106.930 1.733E+02  2.291E-03  263.5   13.9    -.8   .000 Mean
6419.708  19.771              2.24%      1.43%    .79%                     M-76
  2880.0     GRM    .0000     1.14%      3.22%  -2.08%    4.0   -8.5        ranS
                               .76%      2.46%   1.47%   17.3    7.1        sigS
                             -3.74%       .77%  -1.48%   17.2    7.0        ranL
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			3.32%	2.18%	1.30%	15.3	6.2		sigL
			-2.61%	3.99%	-3.56%	21.2	-1.4	-.39	ranT
			3.41%	3.29%	1.97%	23.1	9.4	.86	sigT
			1.688E+02	2.383E-03	254.1	35.1	-2.2	-.39	Tot.
			-.43%	5.47%	-2.80%				T-76
			1.361E-03	1.119E-08	173.8			.0%	H2O
			8.185E-05	6.731E-10	.1			.0%	sigH
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42.000	20.050	-105.730	2.239E+02	3.007E-03	259.4	14.7	-.8	.000	Mean
6417.612	20.173		1.78%	.39%	1.37%				M-76
2940.0	GRM	.0000	1.40%	2.72%	-1.32%	-14.4	-.8		ranS
			.72%	2.29%	1.45%	16.5	6.3		sigS
			-3.56%	.66%	-1.46%	16.5	6.4		ranL
			3.13%	2.03%	1.29%	14.7	5.6		sigL
			-2.15%	3.38%	-2.78%	2.1	5.6	.97	ranT
			3.21%	3.06%	1.94%	22.1	8.4	.81	sigT
			2.191E+02	3.108E-03	252.2	16.8	4.7	.97	Tot.
			-.42%	3.79%	-1.45%				T-76
			1.697E-03	1.418E-08	172.0			.0%	H2O
			8.753E-05	7.313E-10	.2			.0%	sigH
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40.000	20.450	-104.530	2.902E+02	3.961E-03	255.2	14.9	-.9	.000	Mean
6415.515	20.576		1.07%	-.86%	1.94%				M-76
3000.0	GRM	.0000	1.01%	.56%	.45%	16.0	7.6		ranS
			.68%	2.11%	1.44%	15.6	5.5		sigS
			-3.39%	.54%	-1.44%	15.8	5.7		ranL
			2.95%	1.89%	1.29%	14.0	4.9		sigL
			-2.37%	1.10%	-.99%	31.9	13.3	.41	ranT
			3.03%	2.83%	1.93%	21.0	7.4	.75	sigT
			2.833E+02	4.005E-03	252.7	46.8	12.3	.41	Tot.
			-1.33%	.23%	.93%				T-76
			2.383E-03	2.023E-08	170.7			.0%	H2O
			9.956E-05	8.457E-10	.2			.0%	sigH
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38.000	20.850	-103.330	3.787E+02	5.287E-03	249.5	13.9	-1.0	.000	Mean
6413.416	20.978		.42%	-1.47%	1.92%				M-76
3060.0	GRM	.0000	.80%	.79%	.01%	-9.3	1.6		ranS
			.63%	1.99%	1.48%	14.8	5.3		sigS
			-3.20%	.41%	-1.45%	15.1	5.5		ranL
			2.76%	1.78%	1.32%	13.2	4.7		sigL
			-2.40%	1.19%	-1.44%	5.8	7.1	.58	ranT
			2.83%	2.67%	1.99%	19.9	7.1	.70	sigT
			3.696E+02	5.351E-03	245.9	19.7	6.1	.58	Tot.
			-1.99%	-.30%	.45%				T-76
			3.392E-03	2.945E-08	171.7			.0%	H2O
			1.163E-04	1.011E-09	.2			.0%	sigH
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36.000	21.250	-102.130	4.973E+02	7.106E-03	243.8	12.8	-1.0	.000	Mean
6411.316	21.380		-.24%	-2.10%	1.89%				M-76
3120.0	GRM	.0000	.49%	1.32%	-.83%	-14.8	-4.6		ranS
			.58%	1.86%	1.52%	13.9	5.1		sigS
			-2.97%	.27%	-1.44%	14.3	5.3		ranL
			2.54%	1.66%	1.35%	12.4	4.5		sigL
			-2.47%	1.59%	-2.27%	-.5	.8	-.31	ranT
			2.60%	2.49%	2.03%	18.6	6.8	.65	sigT
			4.850E+02	7.219E-03	238.3	12.3	-.3	-.31	Tot.
			-2.71%	-.54%	-.42%				T-76
			4.384E-03	3.896E-08	172.6			.0%	H2O
			1.370E-04	1.219E-09	.2			.0%	sigH
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34.000	21.650	-100.930	6.575E+02	9.614E-03	238.3	12.1	-.9	.000	Mean
6409.214	21.782		-.89%	-2.77%	1.95%				M-76
3180.0	GRM	.0000	.37%	-1.09%	1.46%	12.1	1.1		ranS
			.53%	1.71%	1.48%	12.7	4.7		sigS
			-2.73%	.12%	-1.37%	13.4	4.9		ranL
			2.32%	1.54%	1.33%	11.5	4.2		sigL
			-2.36%	-.97%	.09%	25.5	6.0	-.09	ranT
			2.38%	2.30%	2.00%	17.1	6.3	.61	sigT
			6.420E+02	9.520E-03	238.5	37.6	5.2	-.09	Tot.
			-3.23%	-3.71%	2.04%				T-76
			5.656E-03	5.143E-08	173.7			.0%	H2O
			1.742E-04	1.586E-09	.2			.0%	sigH
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32.000	22.050	-99.730	8.751E+02	1.309E-02	233.0	11.8	-.5	.000	Mean
6407.110	22.184		-1.57%	-3.43%	1.99%				M-76
3240.0	GRM	.0000	.16%	-.92%	1.08%	1.6	-.1		ranS
			.48%	1.54%	1.39%	11.3	4.1		sigS
			-2.49%	-.03%	-1.24%	12.2	4.4		ranL
			2.10%	1.41%	1.28%	10.3	3.8		sigL
			-2.33%	-.96%	-.16%	13.8	4.3	.51	ranT
			2.16%	2.08%	1.89%	15.3	5.6	.57	sigT
			8.547E+02	1.297E-02	232.7	25.6	3.8	.51	Tot.
			-3.86%	-4.35%	1.83%				T-76
			7.338E-03	6.823E-08	174.9			.0%	H2O
			2.126E-04	1.979E-09	.2			.0%	sigH
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30.000	22.450	-98.530	1.172E+03	1.794E-02	227.8	11.2	-.3	.000	Mean
6405.005	22.585		-2.07%	-2.53%	.59%				M-76
3300.0	GRM	.0000	.26%	-1.11%	1.37%	.4	-.7		ranS
			.43%	1.34%	1.30%	9.7	3.4		sigS
			-2.18%	-.18%	-1.09%	10.6	3.7		ranL
			1.86%	1.25%	1.21%	9.1	3.2		sigL
			-1.92%	-1.28%	.28%	11.0	3.0	.32	ranT
			1.91%	1.84%	1.78%	13.3	4.7	.53	sigT
			1.150E+03	1.771E-02	228.5	22.3	2.7	.32	Tot.
			-3.94%	-3.78%	.87%				T-76
			9.671E-03	9.197E-08	176.3			.1%	H2O
			2.613E-04	2.488E-09	.2			.0%	sigH
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28.000	22.850	-97.330	1.582E+03	2.462E-02	224.0	9.7	-.6	.000	Mean
6402.899	22.987		-2.13%	-1.80%	-.26%				M-76
3360.0	GRM	.0000	.22%	-.51%	.72%	.2	4.4		ranS
			.39%	1.23%	1.15%	8.6	3.0		sigS
			-1.94%	-.32%	-.87%	9.5	3.3		ranL
			1.69%	1.18%	1.11%	8.3	2.9		sigL
			-1.72%	-.83%	-.15%	9.7	7.6	.79	ranT
			1.73%	1.71%	1.60%	11.9	4.2	.50	sigT
			1.555E+03	2.442E-02	223.6	19.4	7.1	.79	Tot.
			-3.81%	-2.61%	-.40%				T-76
			1.296E-02	1.253E-07	177.8			.1%	H2O
			3.281E-04	3.178E-09	.2			.0%	sigH
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26.000	23.250	-96.130	2.145E+03	3.398E-02	220.0	8.0	-.7	.000	Mean
6400.791	23.389		-1.96%	-.80%	-1.14%				M-76
3420.0	GRM	.0000	.71%	1.20%	-.49%	-10.7	4.5		ranS
			.35%	1.11%	1.01%	7.4	2.5		sigS
			-1.67%	-.46%	-.64%	8.0	2.7		ranL
			1.51%	1.10%	.99%	7.2	2.5		sigL
			-.96%	.75%	-1.14%	-2.7	7.2	.58	ranT
			1.54%	1.56%	1.41%	10.3	3.6	.47	sigT

			2.125E+03	3.424E-02	217.5	5.3	6.5	.58	Tot.
			-2.90%	-.06%	-2.26%				T-76
			1.726E-02	1.699E-07	179.3			.2%	H2O
			4.662E-04	4.596E-09	.2			.0%	sigH
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24.000	23.650	-94.930	2.927E+03	4.721E-02	216.0	7.1	.3	.000	Mean
6398.682	23.791		-1.51%	.58%	-2.07%				M-76
3480.0	GRM	.0000	.73%	1.31%	-.59%	-1.7	-.9		ranS
			.39%	1.00%	.91%	6.0	2.6		sigS
			-1.76%	-.57%	-.55%	6.3	2.6		ranL
			1.70%	1.00%	.91%	6.0	2.6		sigL
			-1.03%	.74%	-1.13%	4.5	1.7	.76	ranT
			1.74%	1.42%	1.28%	8.4	3.6	.44	sigT
			2.897E+03	4.756E-02	213.5	11.6	2.1	.76	Tot.
			-2.53%	1.33%	-3.18%				T-76
			2.240E-02	2.247E-07	180.7			.5%	H2O
			6.701E-04	6.730E-09	.2			.0%	sigH
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22.000	24.050	-93.730	4.035E+03	6.666E-02	210.9	7.6	1.6	.000	Mean
6396.571	24.193		-.30%	3.33%	-3.51%				M-76
3540.0	GRM	.0000	.43%	.68%	-.24%	-4.6	-.3		ranS
			.28%	.99%	.92%	4.9	2.9		sigS
			-1.16%	-.72%	-.25%	4.8	2.6		ranL
			1.24%	1.00%	.93%	4.9	2.9		sigL
			-.72%	-.04%	-.50%	.2	2.3	.77	ranT
			1.27%	1.41%	1.31%	6.9	4.1	.43	sigT
			4.006E+03	6.663E-02	209.9	7.8	3.9	.77	Tot.
			-1.02%	3.29%	-3.99%				T-76
			2.825E-02	2.902E-07	182.0			1.2%	H2O
			1.010E-03	1.039E-08	.3			.1%	sigH
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20.000	24.450	-92.530	5.608E+03	9.522E-02	205.2	10.0	2.6	.000	Mean
6394.458	24.595		1.43%	7.10%	-5.30%				M-76
3600.0	GRM	.0000	-.10%	1.98%	-2.08%	4.6	-4.3		ranS
			.13%	.96%	.95%	4.4	3.3		sigS
			-.46%	-.85%	.33%	3.8	2.5		ranL
			.58%	.98%	.96%	4.4	3.4		sigL
			-.56%	1.13%	-1.75%	8.4	-1.8	-.49	ranT
			.59%	1.37%	1.35%	6.2	4.8	.42	sigT
			5.577E+03	9.630E-02	201.6	18.4	.8	-.49	Tot.
			.86%	8.31%	-6.96%				T-76
			3.466E-02	3.661E-07	183.1			3.1%	H2O
			1.780E-03	1.882E-08	.4			.2%	sigH
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18.000	24.850	-91.330	7.847E+03	1.357E-01	201.4	16.4	3.7	.000	Mean
6392.345	24.997		3.73%	11.56%	-7.02%				M-76
3660.0	GRM	.0000	.18%	1.43%	-1.26%	9.5	5.4		ranS
			.15%	.96%	.95%	4.9	4.0		sigS
			-.41%	-.99%	.47%	3.5	2.2		ranL
			.67%	.98%	.97%	5.0	4.1		sigL
			-.24%	.44%	-.79%	12.9	7.6	.30	ranT
			.69%	1.37%	1.36%	7.0	5.7	.46	sigT
			7.828E+03	1.363E-01	199.9	29.3	11.3	.30	Tot.
			3.48%	12.05%	-7.75%				T-76
			3.954E-02	4.253E-07	183.8			6.0%	H2O
			4.207E-03	4.530E-08	.9			.8%	sigH
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16.000	25.250	-90.130	1.098E+04	1.881E-01	203.4	25.3	5.5	-.001	Mean
6390.230	25.398		6.06%	13.00%	-6.14%				M-76
3720.0	GRM	.0000	.19%	1.07%	-.89%	10.2	5.3		ranS

			.21%	.88%	.89%	6.2	5.0		sigS
			-.36%	-1.02%	.48%	3.2	1.6		ranL
			.90%	.92%	.92%	6.4	5.2		sigL
			-.17%	.05%	-.41%	13.3	6.8	-1.18	ranT
			.92%	1.27%	1.28%	8.9	7.3	.49	sigT
			1.096E+04	1.882E-01	202.5	38.6	12.4	-1.18	Tot.
			5.88%	13.06%	-6.52%				T-76
			5.484E-02	5.843E-07	185.2			6.0%	H2O
			1.980E-02	2.112E-07	3.6			2.8%	sigH
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14.000	25.650	-88.930	1.523E+04	2.528E-01	209.8	33.9	7.2	-.002	Mean
6388.114	25.800		7.45%	10.95%	-3.15%				M-76
3780.0	GRM	.0000	.08%	-.37%	.45%	-1.5	-5.8		ranS
			.25%	.74%	.73%	7.4	6.5		sigS
			-.16%	-.91%	.44%	2.0	.2		ranL
			1.10%	.78%	.78%	7.8	6.9		sigL
			-.08%	-1.29%	.89%	.4	-5.6	-.22	ranT
			1.13%	1.07%	1.07%	10.7	9.5	.53	sigT
			1.521E+04	2.495E-01	211.7	34.3	1.7	-.22	Tot.
			7.37%	9.52%	-2.29%				T-76
			1.291E-01	1.333E-06	190.1			5.9%	H2O
			4.959E-02	5.128E-07	4.2			2.9%	sigH
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12.000	26.050	-87.730	2.086E+04	3.309E-01	219.6	35.7	7.4	.001	Mean
6385.996	26.202		7.54%	6.09%	1.36%				M-76
3840.0	GRM	.0000	-.01%	-1.10%	1.09%	11.8	1.7		ranS
			.26%	.78%	.78%	8.0	8.0		sigS
			.16%	-.98%	.68%	-.1	-2.2		ranL
			1.13%	.84%	.84%	8.6	8.6		sigL
			.15%	-2.08%	1.77%	11.7	-.4	-.33	ranT
			1.16%	1.14%	1.15%	11.8	11.8	.58	sigT
			2.089E+04	3.240E-01	223.5	47.3	7.0	-.33	Tot.
			7.69%	3.88%	3.16%				T-76
			6.118E-01	6.035E-06	200.1			8.2%	H2O
			2.464E-01	2.436E-06	5.1			4.3%	sigH
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10.000	26.450	-86.530	2.817E+04	4.228E-01	232.1	30.9	5.9	.006	Mean
6383.877	26.604		6.30%	2.25%	3.95%				M-76
3900.0	GRM	.0000	-.12%	-.86%	.74%	22.7	5.9		ranS
			.24%	.60%	.60%	7.7	7.8		sigS
			.45%	-.72%	.62%	-2.5	-4.6		ranL
			1.05%	.66%	.65%	8.4	8.5		sigL
			.33%	-1.58%	1.36%	20.2	1.3	.30	ranT
			1.08%	.89%	.89%	11.3	11.5	.63	sigT
			2.826E+04	4.161E-01	235.2	51.1	7.3	.31	Tot.
			6.65%	.63%	5.36%				T-76
			8.207E+00	7.660E-05	219.9			27.2%	H2O
			3.313E+00	3.100E-05	6.4			15.0%	sigH
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8.000	26.850	-85.330	3.737E+04	5.283E-01	246.4	24.7	4.3	.007	Mean
6381.757	27.005		4.82%	.48%	4.29%				M-76
3960.0	GRM	.0000	-.10%	-.20%	.11%	13.7	-10.3		ranS
			.20%	.60%	.59%	6.6	6.8		sigS
			.62%	-.63%	.74%	-4.3	-6.0		ranL
			.89%	.67%	.65%	7.3	7.5		sigL
			.53%	-.84%	.85%	9.5	-16.3	.91	ranT
			.91%	.90%	.88%	9.9	10.1	.63	sigT
			3.757E+04	5.239E-01	248.4	34.1	-12.0	.92	Tot.
			5.37%	-.36%	5.18%				T-76
			2.829E+01	2.487E-04	234.7			35.6%	H2O

			1.716E+01	1.511E-04	7.6			30.3%	sigH
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6.000	27.250	-84.130	4.883E+04	6.519E-01	260.8	18.5	3.0	.002	Mean
6379.636	27.407		3.41%	-1.24%	4.66%				M-76
4020.0	GRM	.0000	.12%	.28%	-.16%	.8	-5.1		ranS
			.16%	.61%	.60%	5.5	5.6		sigS
			.67%	-.49%	.79%	-5.2	-6.4		ranL
			.71%	.69%	.68%	6.2	6.3		sigL
			.79%	-.21%	.63%	-4.4	-11.5	-.06	ranT
			.73%	.92%	.90%	8.3	8.5	.63	sigT
			4.922E+04	6.506E-01	262.4	14.1	-8.5	-.06	Tot.
			4.23%	-1.44%	5.32%				T-76
			7.734E+01	6.423E-04	245.1			28.5%	H2O
			4.672E+01	3.886E-04	8.2			23.9%	sigH
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4.000	27.650	-82.930	6.294E+04	8.039E-01	272.5	12.9	1.9	.001	Mean
6377.514	27.808		2.08%	-1.88%	3.93%				M-76
4080.0	GRM	.0000	.05%	-.05%	.10%	-.4	-1.9		ranS
			.13%	.60%	.59%	4.8	4.5		sigS
			.63%	-.28%	.69%	-5.8	-5.9		ranL
			.57%	.69%	.68%	5.6	5.1		sigL
			.68%	-.33%	.79%	-6.1	-7.8	.23	ranT
			.59%	.92%	.90%	7.4	6.8	.69	sigT
			6.337E+04	8.013E-01	274.6	6.8	-5.9	.24	Tot.
			2.77%	-2.21%	4.75%				T-76
			2.010E+02	1.597E-03	256.2			30.5%	H2O
			1.172E+02	9.327E-04	8.6			24.5%	sigH
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2.000	28.050	-81.730	8.039E+04	9.912E-01	281.9	6.6	1.2	.002	Mean
6375.390	28.210		1.11%	-1.52%	2.46%				M-76
4140.0	GRM	.0000	.09%	.22%	-.13%	-1.1	-2.4		ranS
			.10%	.81%	.73%	4.3	3.7		sigS
			.53%	-.05%	.48%	-5.7	-5.1		ranL
			.45%	.94%	.85%	5.0	4.3		sigL
			.62%	.17%	.34%	-6.8	-7.5	-1.27	ranT
			.46%	1.24%	1.12%	6.5	5.7	.82	sigT
			8.089E+04	9.929E-01	282.9	-.2	-6.4	-1.27	Tot.
			1.74%	-1.36%	2.81%				T-76
			5.845E+02	4.490E-03	269.3			44.6%	H2O
			3.582E+02	2.757E-03	10.4			38.5%	sigH
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.000	28.450	-80.530	1.021E+05	1.212E+00	291.5	.8	-.6	.000	Mean
6373.265	28.611		.76%	-1.04%	1.17%				M-76
4200.0	GRM	.0000	-.03%	-.46%	.43%	-7.0	-2.9		ranS
			.10%	.75%	.71%	2.8	2.8		sigS
			.51%	.28%	.20%	-3.9	-3.6		ranL
			.45%	.89%	.85%	3.3	3.3		sigL
			.48%	-.18%	.63%	-10.9	-6.5	-.87	ranT
			.46%	1.16%	1.11%	4.4	4.3	.94	sigT
			1.026E+05	1.210E+00	293.4	-10.1	-7.0	-.87	Tot.
			1.24%	-1.22%	1.81%				T-76
			1.759E+03	1.307E-02	288.1			80.5%	H2O
			4.644E+02	3.457E-03	4.2			29.7%	sigH

E.2 Sample Species Concentration Output File Produced by Input File of Appendix D

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   **** Earth Global Reference Atmospheric Model - 2007 (Earth-GRAM-07) ****
                     Version 1, Released October, 2007
                      Species Concentration Data

MM/DD/YYYY =  1/ 1/2007  HH:MM:SS(UTC) =  0: 0:  .0  Julian Day = 2454101.500
F10.7 =  230.00          Mean F10.7 =  230.00        ap Index =  20.30

Standard deviations of concentration variation may be a substantial fraction
(50% or more) of the mean value.  Zero concentration values indicate no
estimate available.

Thermospheric constituents from MET  model

 Height/
 Radius    GcLat    Long.   Concen-   Number    |  Concen-   Number
  (km)     GdLat   [E+W-]   tration   Density   |  tration   Density    Species
Time_sec   (deg)    (deg)    (ppmv)   (#/m**3)  |   (ppmv)   (#/m**3)
-------- ------- --------  --------- --------- + --------- ---------  ----+----
 140.000    .450 -164.530  0.000E+00 0.000E+00 | 0.000E+00 0.000E+00  H2O |  O3
6518.136    .453           0.000E+00 0.000E+00 | 0.000E+00 0.000E+00  N2O |  CO
      .0                   0.000E+00 0.000E+00 | 0.000E+00 0.000E+00  CH4 | CO2
                           6.532E+05 6.830E+16 | 9.206E+04 9.626E+15   N2 |  O2
                           2.523E+05 2.638E+16 | 2.324E+03 2.430E+14    O |  Ar
                           1.894E+02 1.980E+13 | 9.563E-06 9.999E+05   He |   H
                           0.000E+00 0.000E+00 | MW=25.373 1.046E+17    N | Tot
-------- ------- --------  --------- --------- + --------- ---------  ----+----
 138.000    .850 -163.330  0.000E+00 0.000E+00 | 0.000E+00 0.000E+00  H2O |  O3
6516.132    .856           0.000E+00 0.000E+00 | 0.000E+00 0.000E+00  N2O |  CO
    60.0                   0.000E+00 0.000E+00 | 0.000E+00 0.000E+00  CH4 | CO2
                           6.588E+05 7.820E+16 | 9.411E+04 1.117E+16   N2 |  O2
                           2.444E+05 2.901E+16 | 2.440E+03 2.896E+14    O |  Ar
                           1.735E+02 2.060E+13 | 8.424E-06 9.999E+05   He |   H
                           0.000E+00 0.000E+00 | MW=25.477 1.187E+17    N | Tot
-------- ------- --------  --------- --------- + --------- ---------  ----+----
 136.000   1.250 -162.130  0.000E+00 0.000E+00 | 0.000E+00 0.000E+00  H2O |  O3
6514.127   1.258           0.000E+00 0.000E+00 | 0.000E+00 0.000E+00  N2O |  CO
   120.0                   0.000E+00 0.000E+00 | 0.000E+00 0.000E+00  CH4 | CO2
                           6.646E+05 9.017E+16 | 9.625E+04 1.306E+16   N2 |  O2
                           2.364E+05 3.208E+16 | 2.566E+03 3.481E+14    O |  Ar
                           1.582E+02 2.147E+13 | 7.370E-06 1.000E+06   He |   H
                           0.000E+00 0.000E+00 | MW=25.583 1.357E+17    N | Tot
-------- ------- --------  --------- --------- + --------- ---------  ----+----
 134.000   1.650 -160.930  0.000E+00 0.000E+00 | 0.000E+00 0.000E+00  H2O |  O3
6512.120   1.661           0.000E+00 0.000E+00 | 0.000E+00 0.000E+00  N2O |  CO
   180.0                   0.000E+00 0.000E+00 | 0.000E+00 0.000E+00  CH4 | CO2
                           6.704E+05 1.048E+17 | 9.852E+04 1.539E+16   N2 |  O2
                           2.283E+05 3.567E+16 | 2.703E+03 4.224E+14    O |  Ar
                           1.436E+02 2.244E+13 | 6.400E-06 1.000E+06   He |   H
                           0.000E+00 0.000E+00 | MW=25.692 1.563E+17    N | Tot
-------- ------- --------  --------- --------- + --------- ---------  ----+----
 132.000   2.050 -159.730  0.000E+00 0.000E+00 | 0.000E+00 0.000E+00  H2O |  O3
6510.110   2.064           0.000E+00 0.000E+00 | 0.000E+00 0.000E+00  N2O |  CO
   240.0                   0.000E+00 0.000E+00 | 0.000E+00 0.000E+00  CH4 | CO2
                           6.762E+05 1.227E+17 | 1.009E+05 1.831E+16   N2 |  O2
                           2.199E+05 3.991E+16 | 2.855E+03 5.181E+14    O |  Ar
                           1.296E+02 2.352E+13 | 5.510E-06 1.000E+06   He |   H
                           0.000E+00 0.000E+00 | MW=25.805 1.815E+17    N | Tot
-------- ------- --------  --------- --------- + --------- ---------  ----+----
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```
 130.000   2.450 -158.530  0.000E+00 0.000E+00 | 0.000E+00 0.000E+00  H2O |  O3
6508.098   2.466           0.000E+00 0.000E+00 | 0.000E+00 0.000E+00  N2O |  CO
   300.0                   0.000E+00 0.000E+00 | 0.000E+00 0.000E+00  CH4 | CO2
                           6.821E+05 1.451E+17 | 1.034E+05 2.201E+16   N2 |  O2
                           2.113E+05 4.495E+16 | 3.022E+03 6.430E+14    O |  Ar
                           1.162E+02 2.472E+13 | 4.701E-06 1.000E+06   He |   H
                           0.000E+00 0.000E+00 | MW=25.921 2.128E+17    N | Tot
-------- ------- --------  --------- --------- + --------- ---------  ----+----
 128.000   2.850 -157.330  0.000E+00 0.000E+00 | 0.000E+00 0.000E+00  H2O |  O3
6506.084   2.869           0.000E+00 0.000E+00 | 0.000E+00 0.000E+00  N2O |  CO
   360.0                   0.000E+00 0.000E+00 | 0.000E+00 0.000E+00  CH4 | CO2
                           6.881E+05 1.734E+17 | 1.061E+05 2.675E+16   N2 |  O2
                           2.024E+05 5.101E+16 | 3.208E+03 8.085E+14    O |  Ar
                           1.035E+02 2.607E+13 | 3.970E-06 1.000E+06   He |   H
                           0.000E+00 0.000E+00 | MW=26.040 2.520E+17    N | Tot
-------- ------- --------  --------- --------- + --------- ---------  ----+----
 126.000   3.250 -156.130  0.000E+00 0.000E+00 | 0.000E+00 0.000E+00  H2O |  O3
6504.068   3.271           0.000E+00 0.000E+00 | 0.000E+00 0.000E+00  N2O |  CO
   420.0                   0.000E+00 0.000E+00 | 0.000E+00 0.000E+00  CH4 | CO2
                           6.941E+05 2.095E+17 | 1.090E+05 3.291E+16   N2 |  O2
                           1.934E+05 5.837E+16 | 3.417E+03 1.031E+15    O |  Ar
                           9.140E+01 2.759E+13 | 3.315E-06 1.001E+06   He |   H
                           0.000E+00 0.000E+00 | MW=26.164 3.019E+17    N | Tot
-------- ------- --------  --------- --------- + --------- ---------  ----+----
 124.000   3.650 -154.930  0.000E+00 0.000E+00 | 0.000E+00 0.000E+00  H2O |  O3
6502.050   3.674           0.000E+00 0.000E+00 | 0.000E+00 0.000E+00  N2O |  CO
   480.0                   0.000E+00 0.000E+00 | 0.000E+00 0.000E+00  CH4 | CO2
                           7.001E+05 2.565E+17 | 1.121E+05 4.107E+16   N2 |  O2
                           1.840E+05 6.740E+16 | 3.652E+03 1.338E+15    O |  Ar
                           8.003E+01 2.932E+13 | 2.732E-06 1.001E+06   He |   H
                           0.000E+00 0.000E+00 | MW=26.291 3.663E+17    N | Tot
-------- ------- --------  --------- --------- + --------- ---------  ----+----
 122.000   4.050 -153.730  0.000E+00 0.000E+00 | 0.000E+00 0.000E+00  H2O |  O3
6500.030   4.077           0.000E+00 0.000E+00 | 0.000E+00 0.000E+00  N2O |  CO
   540.0                   0.000E+00 0.000E+00 | 0.000E+00 0.000E+00  CH4 | CO2
                           7.062E+05 3.183E+17 | 1.155E+05 5.203E+16   N2 |  O2
                           1.744E+05 7.858E+16 | 3.919E+03 1.766E+15    O |  Ar
                           6.939E+01 3.127E+13 | 2.222E-06 1.001E+06   He |   H
                           0.000E+00 0.000E+00 | MW=26.424 4.507E+17    N | Tot
-------- ------- --------  --------- --------- + --------- ---------  ----+----
 120.000   4.450 -152.530  0.000E+00 0.000E+00 | 0.000E+00 0.000E+00  H2O |  O3
6498.008   4.479           0.000E+00 0.000E+00 | 0.000E+00 0.000E+00  N2O |  CO
   600.0                   0.000E+00 0.000E+00 | 0.000E+00 0.000E+00  CH4 | CO2
                           7.122E+05 4.006E+17 | 1.191E+05 6.697E+16   N2 |  O2
                           1.645E+05 9.251E+16 | 4.224E+03 2.376E+15    O |  Ar
                           5.952E+01 3.348E+13 | 1.781E-06 1.002E+06   He |   H
                           0.000E+00 0.000E+00 | MW=26.561 5.625E+17    N | Tot
-------- ------- --------  --------- --------- + --------- ---------  ----+----
 118.000   4.850 -151.330  2.151E-01 1.530E+11 | 1.248E-03 8.881E+08  H2O |  O3
6495.983   4.882           2.139E-04 1.522E+08 | 5.749E+01 4.090E+13  N2O |  CO
   660.0                   5.214E-02 3.710E+10 | 4.300E+01 3.059E+13  CH4 | CO2
                           7.209E+05 5.129E+17 | 1.201E+05 8.545E+16   N2 |  O2
                           1.543E+05 1.097E+17 | 4.576E+03 3.256E+15    O |  Ar
                           5.046E+01 3.590E+13 | 1.406E-06 1.000E+06   He |   H
                           0.000E+00 0.000E+00 | MW=26.693 7.114E+17    N | Tot
-------- ------- --------  --------- --------- + --------- ---------  ----+----
 116.000   5.250 -150.130  2.314E-01 2.109E+11 | 3.111E-03 2.835E+09  H2O |  O3
6493.957   5.285           2.249E-04 2.050E+08 | 5.313E+01 4.843E+13  N2O |  CO
   720.0                   6.852E-02 6.246E+10 | 4.517E+01 4.117E+13  CH4 | CO2
                           7.289E+05 6.644E+17 | 1.221E+05 1.113E+17   N2 |  O2
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                             1.439E+05 1.311E+17 | 4.988E+03 4.546E+15    O |  Ar
                             4.227E+01 3.853E+13 | 1.093E-06 9.965E+05   He |   H
                             0.000E+00 0.000E+00 | MW=26.831 9.115E+17    N | Tot
-------- ------- --------   --------- --------- + --------- ---------   ----+----
 114.000   5.650 -148.930   2.475E-01 2.939E+11 | 7.756E-03 9.208E+09  H2O |  O3
6491.929   5.687            2.369E-04 2.813E+08 | 4.890E+01 5.806E+13  N2O |  CO
   780.0                    8.598E-02 1.021E+11 | 5.014E+01 5.952E+13  CH4 | CO2
                            7.359E+05 8.737E+17 | 1.251E+05 1.486E+17   N2 |  O2
                            1.333E+05 1.583E+17 | 5.470E+03 6.495E+15    O |  Ar
                            3.494E+01 4.148E+13 | 8.370E-07 9.937E+05   He |   H
                            0.000E+00 0.000E+00 | MW=26.976 1.187E+18    N | Tot
-------- ------- --------   --------- --------- + --------- ---------   ----+----
 112.000   6.050 -147.730   2.633E-01 4.155E+11 | 1.941E-02 3.064E+10  H2O |  O3
6489.898   6.090            2.506E-04 3.956E+08 | 4.495E+01 7.095E+13  N2O |  CO
   840.0                    1.033E-01 1.631E+11 | 5.897E+01 9.308E+13  CH4 | CO2
                            7.421E+05 1.171E+18 | 1.292E+05 2.039E+17   N2 |  O2
                            1.225E+05 1.934E+17 | 6.033E+03 9.522E+15    O |  Ar
                            2.845E+01 4.491E+13 | 6.300E-07 9.945E+05   He |   H
                            0.000E+00 0.000E+00 | MW=27.129 1.578E+18    N | Tot
-------- ------- --------   --------- --------- + --------- ---------   ----+----
 110.000   6.450 -146.530   2.800E-01 6.042E+11 | 4.896E-02 1.056E+11  H2O |  O3
6487.866   6.492            2.673E-04 5.768E+08 | 4.164E+01 8.985E+13  N2O |  CO
   900.0                    1.252E-01 2.702E+11 | 6.991E+01 1.509E+14  CH4 | CO2
                            7.475E+05 1.613E+18 | 1.345E+05 2.902E+17   N2 |  O2
                            1.112E+05 2.400E+17 | 6.669E+03 1.439E+16    O |  Ar
                            2.273E+01 4.906E+13 | 4.648E-07 1.003E+06   He |   H
                            0.000E+00 0.000E+00 | MW=27.294 2.158E+18    N | Tot
-------- ------- --------   --------- --------- + --------- ---------   ----+----
 108.000   6.850 -145.330   3.026E-01 9.059E+11 | 8.551E-02 2.560E+11  H2O |  O3
6485.832   6.895            2.860E-04 8.563E+08 | 3.708E+01 1.110E+14  N2O |  CO
   960.0                    1.337E-01 4.003E+11 | 8.973E+01 2.686E+14  CH4 | CO2
                            7.528E+05 2.254E+18 | 1.396E+05 4.178E+17   N2 |  O2
                            1.001E+05 2.995E+17 | 7.419E+03 2.221E+16    O |  Ar
                            1.789E+01 5.357E+13 | 3.377E-07 1.011E+06   He |   H
                            0.000E+00 0.000E+00 | MW=27.457 2.994E+18    N | Tot
-------- ------- --------   --------- --------- + --------- ---------   ----+----
 106.000   7.250 -144.130   3.271E-01 1.391E+12 | 1.499E-01 6.377E+11  H2O |  O3
6483.795   7.298            3.073E-04 1.307E+09 | 3.315E+01 1.410E+14  N2O |  CO
  1020.0                    1.433E-01 6.096E+11 | 1.156E+02 4.916E+14  CH4 | CO2
                            7.576E+05 3.222E+18 | 1.453E+05 6.181E+17   N2 |  O2
                            8.867E+04 3.771E+17 | 8.257E+03 3.512E+16    O |  Ar
                            1.379E+01 5.866E+13 | 2.404E-07 1.022E+06   He |   H
                            0.000E+00 0.000E+00 | MW=27.627 4.253E+18    N | Tot
-------- ------- --------   --------- --------- + --------- ---------   ----+----
 104.000   7.650 -142.930   3.512E-01 2.154E+12 | 2.287E-01 1.402E+12  H2O |  O3
6481.756   7.700            3.301E-04 2.024E+09 | 2.925E+01 1.794E+14  N2O |  CO
  1080.0                    1.517E-01 9.304E+11 | 1.478E+02 9.065E+14  CH4 | CO2
                            7.627E+05 4.678E+18 | 1.516E+05 9.300E+17   N2 |  O2
                            7.678E+04 4.709E+17 | 8.678E+03 5.322E+16    O |  Ar
                            1.197E+01 7.343E+13 | 1.684E-07 1.033E+06   He |   H
                            0.000E+00 0.000E+00 | MW=27.801 6.133E+18    N | Tot
-------- ------- --------   --------- --------- + --------- ---------   ----+----
 102.000   8.050 -141.730   3.748E-01 3.328E+12 | 3.021E-01 2.682E+12  H2O |  O3
6479.716   8.103            3.532E-04 3.136E+09 | 2.538E+01 2.253E+14  N2O |  CO
  1140.0                    1.579E-01 1.402E+12 | 1.868E+02 1.658E+15  CH4 | CO2
                            7.684E+05 6.822E+18 | 1.583E+05 1.405E+18   N2 |  O2
                            6.450E+04 5.727E+17 | 8.614E+03 7.648E+16    O |  Ar
                            1.188E+01 1.055E+14 | 1.170E-07 1.038E+06   He |   H
                            0.000E+00 0.000E+00 | MW=27.975 8.879E+18    N | Tot
-------- ------- --------   --------- --------- + --------- ---------   ----+----
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 100.000   8.450 -140.530  4.000E-01 5.195E+12 | 3.985E-01 5.175E+12  H2O |  O3
6477.673   8.505           3.773E-04 4.899E+09 | 2.198E+01 2.855E+14  N2O |  CO
   1200.0                  1.641E-01 2.130E+12 | 2.357E+02 3.061E+15  CH4 | CO2
                           7.736E+05 1.005E+19 | 1.654E+05 2.148E+18   N2 |  O2
                           5.228E+04 6.790E+17 | 8.510E+03 1.105E+17    O |  Ar
                           1.174E+01 1.525E+14 | 8.023E-08 1.042E+06   He |   H
                           0.000E+00 0.000E+00 | MW=28.149 1.299E+19    N | Tot
-------- ------- --------  --------- --------- + --------- ---------  ----+----
  98.000   8.850 -139.330  4.510E-01 8.484E+12 | 4.348E-01 8.178E+12  H2O |  O3
6475.628   8.908           4.043E-04 7.606E+09 | 1.805E+01 3.395E+14  N2O |  CO
   1260.0                  1.697E-01 3.192E+12 | 2.690E+02 5.059E+15  CH4 | CO2
                           7.815E+05 1.470E+19 | 1.731E+05 3.255E+18   N2 |  O2
                           3.659E+04 6.883E+17 | 8.513E+03 1.601E+17    O |  Ar
                           1.175E+01 2.209E+14 | 5.546E-08 1.043E+06   He |   H
                           0.000E+00 0.000E+00 | MW=28.369 1.881E+19    N | Tot
-------- ------- --------  --------- --------- + --------- ---------  ----+----
  96.000   9.250 -138.130  5.085E-01 1.384E+13 | 4.726E-01 1.286E+13  H2O |  O3
6473.582   9.310           4.317E-04 1.175E+10 | 1.477E+01 4.018E+14  N2O |  CO
   1320.0                  1.749E-01 4.759E+12 | 3.058E+02 8.320E+15  CH4 | CO2
                           7.873E+05 2.142E+19 | 1.808E+05 4.920E+18   N2 |  O2
                           2.302E+04 6.262E+17 | 8.511E+03 2.316E+17    O |  Ar
                           1.174E+01 3.195E+14 | 3.824E-08 1.040E+06   He |   H
                           0.000E+00 0.000E+00 | MW=28.564 2.721E+19    N | Tot
-------- ------- --------  --------- --------- + --------- ---------  ----+----
  94.000   9.650 -136.930  5.913E-01 2.324E+13 | 4.946E-01 1.944E+13  H2O |  O3
6471.533   9.713           4.615E-04 1.814E+10 | 1.216E+01 4.780E+14  N2O |  CO
   1380.0                  1.798E-01 7.065E+12 | 3.344E+02 1.314E+16  CH4 | CO2
                           7.918E+05 3.112E+19 | 1.869E+05 7.345E+18   N2 |  O2
                           1.243E+04 4.886E+17 | 8.504E+03 3.342E+17    O |  Ar
                           1.173E+01 4.611E+14 | 2.636E-08 1.036E+06   He |   H
                           0.000E+00 0.000E+00 | MW=28.715 3.930E+19    N | Tot
-------- ------- --------  --------- --------- + --------- ---------  ----+----
  92.000  10.050 -135.730  7.089E-01 3.998E+13 | 4.981E-01 2.809E+13  H2O |  O3
6469.483  10.115           4.938E-04 2.785E+10 | 1.009E+01 5.689E+14  N2O |  CO
   1440.0                  1.843E-01 1.039E+13 | 3.517E+02 1.984E+16  CH4 | CO2
                           7.949E+05 4.483E+19 | 1.906E+05 1.075E+19   N2 |  O2
                           5.558E+03 3.134E+17 | 8.515E+03 4.802E+17    O |  Ar
                           1.175E+01 6.625E+14 | 1.825E-08 1.029E+06   He |   H
                           0.000E+00 0.000E+00 | MW=28.813 5.640E+19    N | Tot
-------- ------- --------  --------- --------- + --------- ---------  ----+----
  90.000  10.450 -134.530  8.500E-01 6.816E+13 | 4.996E-01 4.007E+13  H2O |  O3
6467.430  10.518           5.263E-04 4.221E+10 | 8.331E+00 6.681E+14  N2O |  CO
   1500.0                  1.882E-01 1.509E+13 | 3.685E+02 2.955E+16  CH4 | CO2
                           7.943E+05 6.370E+19 | 1.935E+05 1.552E+19   N2 |  O2
                           2.299E+03 1.843E+17 | 9.511E+03 7.628E+17    O |  Ar
                           5.295E+00 4.247E+14 | 0.000E+00 0.000E+00   He |   H
                           0.000E+00 0.000E+00 | MW=28.876 8.019E+19    N | Tot
-------- ------- --------  --------- --------- + --------- ---------  ----+----
  88.000  10.850 -133.330  1.007E+00 1.127E+14 | 4.885E-01 5.463E+13  H2O |  O3
6465.376  10.920           5.672E-04 6.343E+10 | 6.700E+00 7.492E+14  N2O |  CO
   1560.0                  1.929E-01 2.157E+13 | 3.721E+02 4.161E+16  CH4 | CO2
                           7.923E+05 8.860E+19 | 1.969E+05 2.202E+19   N2 |  O2
                           8.944E+02 1.000E+17 | 9.483E+03 1.061E+18    O |  Ar
                           5.280E+00 5.904E+14 | 0.000E+00 0.000E+00   He |   H
                           0.000E+00 0.000E+00 | MW=28.906 1.118E+20    N | Tot
-------- ------- --------  --------- --------- + --------- ---------  ----+----
  86.000  11.250 -132.130  1.194E+00 1.851E+14 | 4.036E-01 6.257E+13  H2O |  O3
6463.319  11.323           6.106E-04 9.467E+10 | 5.383E+00 8.345E+14  N2O |  CO
   1620.0                  1.975E-01 3.063E+13 | 3.754E+02 5.820E+16  CH4 | CO2
                           7.896E+05 1.224E+20 | 2.002E+05 3.104E+19   N2 |  O2
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                                3.505E+02 5.434E+16 | 9.447E+03 1.465E+18    O |  Ar
                                5.259E+00 8.154E+14 | 0.000E+00 0.000E+00   He |   H
                                0.000E+00 0.000E+00 | MW=28.926 1.550E+20    N | Tot
-------- ------- --------   --------- --------- + --------- ---------  ----+----
  84.000  11.650 -130.930   1.431E+00 3.056E+14 | 3.501E-01 7.477E+13  H2O |  O3
6461.261  11.725            6.595E-04 1.408E+11 | 4.014E+00 8.572E+14  N2O |  CO
   1680.0                   1.995E-01 4.260E+13 | 3.782E+02 8.075E+16  CH4 | CO2
                            7.867E+05 1.680E+20 | 2.034E+05 4.343E+19   N2 |  O2
                            1.685E+02 3.599E+16 | 9.410E+03 2.009E+18    O |  Ar
                            5.239E+00 1.119E+15 | 0.000E+00 0.000E+00   He |   H
                            0.000E+00 0.000E+00 | MW=28.940 2.135E+20    N | Tot
-------- ------- --------   --------- --------- + --------- ---------  ----+----
  82.000  12.050 -129.730   1.733E+00 5.072E+14 | 3.295E-01 9.641E+13  H2O |  O3
6459.201  12.128            7.148E-04 2.091E+11 | 2.779E+00 8.131E+14  N2O |  CO
   1740.0                   1.988E-01 5.815E+13 | 3.805E+02 1.113E+17  CH4 | CO2
                            7.837E+05 2.293E+20 | 2.064E+05 6.039E+19   N2 |  O2
                            9.898E+01 2.896E+16 | 9.375E+03 2.743E+18    O |  Ar
                            5.219E+00 1.527E+15 | 0.000E+00 0.000E+00   He |   H
                            0.000E+00 0.000E+00 | MW=28.953 2.926E+20    N | Tot
-------- ------- --------   --------- --------- + --------- ---------  ----+----
  80.000  12.450 -128.530   1.915E+00 7.646E+14 | 2.849E-01 1.138E+14  H2O |  O3
6457.139  12.530            7.746E-04 3.093E+11 | 1.924E+00 7.684E+14  N2O |  CO
   1800.0                   1.980E-01 7.907E+13 | 3.828E+02 1.529E+17  CH4 | CO2
                            7.808E+05 3.118E+20 | 2.095E+05 8.364E+19   N2 |  O2
                            5.821E+01 2.324E+16 | 9.339E+03 3.730E+18    O |  Ar
                            5.200E+00 2.076E+15 | 0.000E+00 0.000E+00   He |   H
                            0.000E+00 0.000E+00 | MW=28.965 3.994E+20    N | Tot
-------- ------- --------   --------- --------- + --------- ---------  ----+----
  78.000  12.850 -127.330   1.614E+00 8.785E+14 | 2.178E-01 1.186E+14  H2O |  O3
6455.074  12.933            8.495E-04 4.625E+11 | 1.289E+00 7.016E+14  N2O |  CO
   1860.0                   1.980E-01 1.078E+14 | 3.838E+02 2.089E+17  CH4 | CO2
                            7.808E+05 4.251E+20 | 2.095E+05 1.140E+20   N2 |  O2
                            2.498E+01 1.360E+16 | 9.339E+03 5.085E+18    O |  Ar
                            5.200E+00 2.831E+15 | 0.000E+00 0.000E+00   He |   H
                            0.000E+00 0.000E+00 | MW=28.965 5.444E+20    N | Tot
-------- ------- --------   --------- --------- + --------- ---------  ----+----
  76.000  13.250 -126.130   1.789E+00 1.324E+15 | 1.667E-01 1.234E+14  H2O |  O3
6453.008  13.335            9.315E-04 6.895E+11 | 8.631E-01 6.388E+14  N2O |  CO
   1920.0                   1.980E-01 1.466E+14 | 3.847E+02 2.847E+17  CH4 | CO2
                            7.808E+05 5.779E+20 | 2.095E+05 1.550E+20   N2 |  O2
                            1.081E+01 8.002E+15 | 9.340E+03 6.913E+18    O |  Ar
                            5.200E+00 3.849E+15 | 0.000E+00 0.000E+00   He |   H
                            0.000E+00 0.000E+00 | MW=28.966 7.402E+20    N | Tot
-------- ------- --------   --------- --------- + --------- ---------  ----+----
  74.000  13.650 -124.930   1.982E+00 1.981E+15 | 1.530E-01 1.528E+14  H2O |  O3
6450.940  13.737            1.027E-03 1.026E+12 | 5.696E-01 5.691E+14  N2O |  CO
   1980.0                   1.980E-01 1.979E+14 | 3.852E+02 3.849E+17  CH4 | CO2
                            7.808E+05 7.802E+20 | 2.095E+05 2.093E+20   N2 |  O2
                            5.821E+00 5.817E+15 | 9.340E+03 9.332E+18    O |  Ar
                            5.200E+00 5.196E+15 | 0.000E+00 0.000E+00   He |   H
                            0.000E+00 0.000E+00 | MW=28.966 9.992E+20    N | Tot
-------- ------- --------   --------- --------- + --------- ---------  ----+----
  72.000  14.050 -123.730   2.641E+00 3.530E+15 | 1.847E-01 2.469E+14  H2O |  O3
6448.871  14.140            1.138E-03 1.522E+12 | 3.704E-01 4.950E+14  N2O |  CO
   2040.0                   1.980E-01 2.647E+14 | 3.852E+02 5.148E+17  CH4 | CO2
                            7.808E+05 1.044E+21 | 2.095E+05 2.800E+20   N2 |  O2
                            3.875E+00 5.180E+15 | 9.340E+03 1.248E+19    O |  Ar
                            5.200E+00 6.950E+15 | 0.000E+00 0.000E+00   He |   H
                            0.000E+00 0.000E+00 | MW=28.966 1.337E+21    N | Tot
-------- ------- --------   --------- --------- + --------- ---------  ----+----
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  70.000  14.450 -122.530  3.457E+00 6.148E+15 | 2.336E-01 4.154E+14  H2O |  O3
6446.799  14.542           1.262E-03 2.244E+12 | 2.408E-01 4.282E+14  N2O |  CO
   2100.0                  1.980E-01 3.521E+14 | 3.852E+02 6.849E+17  CH4 | CO2
                           7.808E+05 1.388E+21 | 2.095E+05 3.725E+20   N2 |  O2
                           2.579E+00 4.587E+15 | 9.340E+03 1.661E+19    O |  Ar
                           5.200E+00 9.247E+15 | 0.000E+00 0.000E+00   He |   H
                           0.000E+00 0.000E+00 | MW=28.966 1.778E+21    N | Tot
-------- ------- --------  --------- --------- + --------- ---------  ----+----
  68.000  14.850 -121.330  4.134E+00 9.631E+15 | 3.152E-01 7.344E+14  H2O |  O3
6444.726  14.945           1.407E-03 3.278E+12 | 1.786E-01 4.161E+14  N2O |  CO
   2160.0                  1.980E-01 4.613E+14 | 3.852E+02 8.973E+17  CH4 | CO2
                           7.808E+05 1.819E+21 | 2.095E+05 4.880E+20   N2 |  O2
                           2.164E+00 5.043E+15 | 9.340E+03 2.176E+19    O |  Ar
                           5.200E+00 1.211E+16 | 0.000E+00 0.000E+00   He |   H
                           0.000E+00 0.000E+00 | MW=28.966 2.330E+21    N | Tot
-------- ------- --------  --------- --------- + --------- ---------  ----+----
  66.000  15.250 -120.130  4.919E+00 1.491E+16 | 4.235E-01 1.284E+15  H2O |  O3
6442.651  15.347           1.567E-03 4.751E+12 | 1.345E-01 4.077E+14  N2O |  CO
   2220.0                  1.980E-01 6.002E+14 | 3.852E+02 1.167E+18  CH4 | CO2
                           7.808E+05 2.367E+21 | 2.095E+05 6.349E+20   N2 |  O2
                           1.827E+00 5.536E+15 | 9.340E+03 2.831E+19    O |  Ar
                           5.200E+00 1.576E+16 | 0.000E+00 0.000E+00   He |   H
                           0.000E+00 0.000E+00 | MW=28.966 3.031E+21    N | Tot
-------- ------- --------  --------- --------- + --------- ---------  ----+----
  64.000  15.650 -118.930  5.349E+00 2.102E+16 | 5.475E-01 2.151E+15  H2O |  O3
6440.574  15.749           1.082E-03 4.252E+12 | 1.122E-01 4.407E+14  N2O |  CO
   2280.0                  1.636E-01 6.429E+14 | 3.852E+02 1.513E+18  CH4 | CO2
                           7.808E+05 3.068E+21 | 2.095E+05 8.231E+20   N2 |  O2
                           1.520E+00 5.974E+15 | 9.340E+03 3.670E+19    O |  Ar
                           5.200E+00 2.043E+16 | 0.000E+00 0.000E+00   He |   H
                           0.000E+00 0.000E+00 | MW=28.966 3.929E+21    N | Tot
-------- ------- --------  --------- --------- + --------- ---------  ----+----
  62.000  16.050 -117.730  5.755E+00 2.925E+16 | 7.080E-01 3.598E+15  H2O |  O3
6438.495  16.152           1.198E-03 6.086E+12 | 1.022E-01 5.195E+14  N2O |  CO
   2340.0                  1.772E-01 9.004E+14 | 3.852E+02 1.957E+18  CH4 | CO2
                           7.808E+05 3.968E+21 | 2.095E+05 1.064E+21   N2 |  O2
                           1.246E+00 6.334E+15 | 9.340E+03 4.746E+19    O |  Ar
                           5.200E+00 2.642E+16 | 0.000E+00 0.000E+00   He |   H
                           0.000E+00 0.000E+00 | MW=28.966 5.082E+21    N | Tot
-------- ------- --------  --------- --------- + --------- ---------  ----+----
  60.000  16.450 -116.530  5.935E+00 3.881E+16 | 9.139E-01 5.975E+15  H2O |  O3
6436.415  16.554           1.374E-03 8.983E+12 | 9.282E-02 6.069E+14  N2O |  CO
   2400.0                  1.927E-01 1.260E+15 | 3.852E+02 2.518E+18  CH4 | CO2
                           7.808E+05 5.105E+21 | 2.095E+05 1.370E+21   N2 |  O2
                           1.026E+00 6.706E+15 | 9.340E+03 6.107E+19    O |  Ar
                           5.200E+00 3.400E+16 | 0.000E+00 0.000E+00   He |   H
                           0.000E+00 0.000E+00 | MW=28.966 6.539E+21    N | Tot
-------- ------- --------  --------- --------- + --------- ---------  ----+----
  58.000  16.850 -115.330  5.787E+00 4.843E+16 | 1.160E+00 9.704E+15  H2O |  O3
6434.332  16.956           1.612E-03 1.349E+13 | 8.798E-02 7.363E+14  N2O |  CO
   2460.0                  2.127E-01 1.780E+15 | 3.852E+02 3.223E+18  CH4 | CO2
                           7.808E+05 6.534E+21 | 2.095E+05 1.753E+21   N2 |  O2
                           7.801E-01 6.528E+15 | 9.340E+03 7.816E+19    O |  Ar
                           5.200E+00 4.352E+16 | 0.000E+00 0.000E+00   He |   H
                           0.000E+00 0.000E+00 | MW=28.966 8.369E+21    N | Tot
-------- ------- --------  --------- --------- + --------- ---------  ----+----
  56.000  17.250 -114.130  5.644E+00 6.016E+16 | 1.394E+00 1.486E+16  H2O |  O3
6432.248  17.358           2.001E-03 2.132E+13 | 8.292E-02 8.837E+14  N2O |  CO
   2520.0                  2.555E-01 2.724E+15 | 3.852E+02 4.105E+18  CH4 | CO2
                           7.808E+05 8.322E+21 | 2.095E+05 2.233E+21   N2 |  O2
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                          5.963E-01 6.356E+15 | 9.340E+03 9.955E+19    O |  Ar
                          5.200E+00 5.542E+16 | 0.000E+00 0.000E+00   He |   H
                          0.000E+00 0.000E+00 | MW=28.966 1.066E+22    N | Tot
-------- ------- --------  --------- --------- + --------- ---------  ----+----
  54.000  17.650 -112.930 5.508E+00 7.480E+16 | 1.661E+00 2.256E+16  H2O |  O3
6430.162  17.761          2.616E-03 3.552E+13 | 7.725E-02 1.049E+15  N2O |  CO
   2580.0                 3.143E-01 4.268E+15 | 3.852E+02 5.230E+18  CH4 | CO2
                          7.808E+05 1.060E+22 | 2.095E+05 2.844E+21   N2 |  O2
                          4.312E-01 5.855E+15 | 9.340E+03 1.268E+20    O |  Ar
                          5.200E+00 7.061E+16 | 0.000E+00 0.000E+00   He |   H
                          0.000E+00 0.000E+00 | MW=28.966 1.358E+22    N | Tot
-------- ------- --------  --------- --------- + --------- ---------  ----+----
  52.000  18.050 -111.730 5.500E+00 9.535E+16 | 1.942E+00 3.367E+16  H2O |  O3
6428.075  18.163          3.397E-03 5.890E+13 | 7.106E-02 1.232E+15  N2O |  CO
   2640.0                 3.645E-01 6.320E+15 | 3.852E+02 6.677E+18  CH4 | CO2
                          7.808E+05 1.354E+22 | 2.095E+05 3.631E+21   N2 |  O2
                          2.944E-01 5.103E+15 | 9.340E+03 1.619E+20    O |  Ar
                          5.200E+00 9.014E+16 | 0.000E+00 0.000E+00   He |   H
                          0.000E+00 0.000E+00 | MW=28.966 1.734E+22    N | Tot
-------- ------- --------  --------- --------- + --------- ---------  ----+----
  50.000  18.450 -110.530 5.325E+00 1.175E+17 | 2.334E+00 5.152E+16  H2O |  O3
6425.986  18.565          4.202E-03 9.277E+13 | 6.486E-02 1.432E+15  N2O |  CO
   2700.0                 4.060E-01 8.961E+15 | 3.852E+02 8.502E+18  CH4 | CO2
                          7.808E+05 1.724E+22 | 2.095E+05 4.624E+21   N2 |  O2
                          2.013E-01 4.444E+15 | 9.340E+03 2.062E+20    O |  Ar
                          5.200E+00 1.148E+17 | 0.000E+00 0.000E+00   He |   H
                          0.000E+00 0.000E+00 | MW=28.966 2.207E+22    N | Tot
-------- ------- --------  --------- --------- + --------- ---------  ----+----
  48.000  18.850 -109.330 5.087E+00 1.447E+17 | 2.865E+00 8.150E+16  H2O |  O3
6423.895  18.967          5.118E-03 1.456E+14 | 5.645E-02 1.606E+15  N2O |  CO
   2760.0                 4.430E-01 1.260E+16 | 3.852E+02 1.096E+19  CH4 | CO2
                          7.808E+05 2.221E+22 | 2.095E+05 5.958E+21   N2 |  O2
                          1.136E-01 3.232E+15 | 9.340E+03 2.657E+20    O |  Ar
                          5.200E+00 1.479E+17 | 0.000E+00 0.000E+00   He |   H
                          0.000E+00 0.000E+00 | MW=28.966 2.844E+22    N | Tot
-------- ------- --------  --------- --------- + --------- ---------  ----+----
  46.000  19.250 -108.130 5.016E+00 1.840E+17 | 3.557E+00 1.304E+17  H2O |  O3
6421.802  19.369          6.670E-03 2.446E+14 | 5.024E-02 1.843E+15  N2O |  CO
   2820.0                 4.883E-01 1.791E+16 | 3.852E+02 1.413E+19  CH4 | CO2
                          7.808E+05 2.863E+22 | 2.095E+05 7.682E+21   N2 |  O2
                          6.410E-02 2.351E+15 | 9.340E+03 3.425E+20    O |  Ar
                          5.200E+00 1.907E+17 | 0.000E+00 0.000E+00   He |   H
                          0.000E+00 0.000E+00 | MW=28.966 3.667E+22    N | Tot
-------- ------- --------  --------- --------- + --------- ---------  ----+----
  44.000  19.650 -106.930 4.883E+00 2.326E+17 | 4.393E+00 2.093E+17  H2O |  O3
6419.708  19.771          9.233E-03 4.398E+14 | 4.503E-02 2.145E+15  N2O |  CO
   2880.0                 5.503E-01 2.622E+16 | 3.852E+02 1.835E+19  CH4 | CO2
                          7.808E+05 3.720E+22 | 2.095E+05 9.979E+21   N2 |  O2
                          3.176E-02 1.513E+15 | 9.340E+03 4.449E+20    O |  Ar
                          5.200E+00 2.477E+17 | 0.000E+00 0.000E+00   He |   H
                          0.000E+00 0.000E+00 | MW=28.966 4.764E+22    N | Tot
-------- ------- --------  --------- --------- + --------- ---------  ----+----
  42.000  20.050 -105.730 4.712E+00 2.946E+17 | 5.304E+00 3.316E+17  H2O |  O3
6417.612  20.173          1.287E-02 8.045E+14 | 4.039E-02 2.525E+15  N2O |  CO
   2940.0                 6.161E-01 3.852E+16 | 3.852E+02 2.408E+19  CH4 | CO2
                          7.808E+05 4.881E+22 | 2.095E+05 1.309E+22   N2 |  O2
                          1.375E-02 8.593E+14 | 9.340E+03 5.839E+20    O |  Ar
                          5.200E+00 3.251E+17 | 0.000E+00 0.000E+00   He |   H
                          0.000E+00 0.000E+00 | MW=28.966 6.252E+22    N | Tot
-------- ------- --------  --------- --------- + --------- ---------  ----+----
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  40.000  20.450 -104.530  5.102E+00 4.203E+17 | 6.245E+00 5.144E+17  H2O |  O3
6415.515  20.576           1.712E-02 1.411E+15 | 3.644E-02 3.001E+15  N2O |  CO
  3000.0                   6.697E-01 5.516E+16 | 3.852E+02 3.173E+19  CH4 | CO2
                           7.808E+05 6.431E+22 | 2.095E+05 1.725E+22   N2 |  O2
                           5.895E-03 4.856E+14 | 9.340E+03 7.693E+20    O |  Ar
                           5.200E+00 4.283E+17 | 0.000E+00 0.000E+00   He |   H
                           0.000E+00 0.000E+00 | MW=28.966 8.237E+22    N | Tot
-------- ------- --------  --------- --------- + --------- ---------  ----+----
  38.000  20.850 -103.330  5.566E+00 6.120E+17 | 6.949E+00 7.640E+17  H2O |  O3
6413.416  20.978           2.530E-02 2.782E+15 | 3.310E-02 3.639E+15  N2O |  CO
  3060.0                   7.444E-01 8.184E+16 | 3.852E+02 4.234E+19  CH4 | CO2
                           7.808E+05 8.584E+22 | 2.095E+05 2.303E+22   N2 |  O2
                           0.000E+00 0.000E+00 | 9.340E+03 1.027E+21    O |  Ar
                           5.200E+00 5.717E+17 | 0.000E+00 0.000E+00   He |   H
                           0.000E+00 0.000E+00 | MW=28.966 1.099E+23    N | Tot
-------- ------- --------  --------- --------- + --------- ---------  ----+----
  36.000  21.250 -102.130  5.479E+00 8.095E+17 | 7.629E+00 1.127E+18  H2O |  O3
6411.316  21.380           4.212E-02 6.223E+15 | 3.053E-02 4.511E+15  N2O |  CO
  3120.0                   8.691E-01 1.284E+17 | 3.852E+02 5.691E+19  CH4 | CO2
                           7.808E+05 1.154E+23 | 2.095E+05 3.095E+22   N2 |  O2
                           0.000E+00 0.000E+00 | 9.340E+03 1.380E+21    O |  Ar
                           5.200E+00 7.682E+17 | 0.000E+00 0.000E+00   He |   H
                           0.000E+00 0.000E+00 | MW=28.966 1.477E+23    N | Tot
-------- ------- --------  --------- --------- + --------- ---------  ----+----
  34.000  21.650 -100.930  5.347E+00 1.069E+18 | 7.807E+00 1.560E+18  H2O |  O3
6409.214  21.782           8.043E-02 1.607E+16 | 2.833E-02 5.661E+15  N2O |  CO
  3180.0                   1.059E+00 2.117E+17 | 3.852E+02 7.698E+19  CH4 | CO2
                           7.808E+05 1.560E+23 | 2.095E+05 4.186E+22   N2 |  O2
                           0.000E+00 0.000E+00 | 9.340E+03 1.867E+21    O |  Ar
                           5.200E+00 1.039E+18 | 0.000E+00 0.000E+00   He |   H
                           0.000E+00 0.000E+00 | MW=28.966 1.999E+23    N | Tot
-------- ------- --------  --------- --------- + --------- ---------  ----+----
  32.000  22.050  -99.730  5.213E+00 1.418E+18 | 7.726E+00 2.101E+18  H2O |  O3
6407.110  22.184           1.078E-01 2.931E+16 | 2.617E-02 7.118E+15  N2O |  CO
  3240.0                   1.182E+00 3.215E+17 | 3.852E+02 1.048E+20  CH4 | CO2
                           7.808E+05 2.124E+23 | 2.095E+05 5.697E+22   N2 |  O2
                           0.000E+00 0.000E+00 | 9.340E+03 2.540E+21    O |  Ar
                           5.200E+00 1.414E+18 | 0.000E+00 0.000E+00   He |   H
                           0.000E+00 0.000E+00 | MW=28.966 2.720E+23    N | Tot
-------- ------- --------  --------- --------- + --------- ---------  ----+----
  30.000  22.450  -98.530  5.129E+00 1.911E+18 | 7.355E+00 2.741E+18  H2O |  O3
6405.005  22.585           1.378E-01 5.134E+16 | 2.382E-02 8.878E+15  N2O |  CO
  3300.0                   1.318E+00 4.910E+17 | 3.852E+02 1.435E+20  CH4 | CO2
                           7.808E+05 2.910E+23 | 2.095E+05 7.806E+22   N2 |  O2
                           0.000E+00 0.000E+00 | 9.340E+03 3.481E+21    O |  Ar
                           5.200E+00 1.938E+18 | 0.000E+00 0.000E+00   He |   H
                           0.000E+00 0.000E+00 | MW=28.966 3.727E+23    N | Tot
-------- ------- --------  --------- --------- + --------- ---------  ----+----
  28.000  22.850  -97.330  5.092E+00 2.605E+18 | 6.740E+00 3.448E+18  H2O |  O3
6402.899  22.987           1.816E-01 9.291E+16 | 2.147E-02 1.098E+16  N2O |  CO
  3360.0                   1.456E+00 7.447E+17 | 3.852E+02 1.970E+20  CH4 | CO2
                           7.808E+05 3.994E+23 | 2.095E+05 1.072E+23   N2 |  O2
                           0.000E+00 0.000E+00 | 9.340E+03 4.778E+21    O |  Ar
                           5.200E+00 2.660E+18 | 0.000E+00 0.000E+00   He |   H
                           0.000E+00 0.000E+00 | MW=28.966 5.116E+23    N | Tot
-------- ------- --------  --------- --------- + --------- ---------  ----+----
  26.000  23.250  -96.130  5.000E+00 3.532E+18 | 5.975E+00 4.220E+18  H2O |  O3
6400.791  23.389           1.573E-01 1.111E+17 | 1.961E-02 1.385E+16  N2O |  CO
  3420.0                   1.251E+00 8.835E+17 | 3.852E+02 2.720E+20  CH4 | CO2
                           7.808E+05 5.515E+23 | 2.095E+05 1.479E+23   N2 |  O2
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                            0.000E+00 0.000E+00 | 9.340E+03 6.596E+21    O |  Ar
                            5.200E+00 3.672E+18 | 0.000E+00 0.000E+00   He |   H
                            0.000E+00 0.000E+00 | MW=28.966 7.063E+23    N | Tot
-------- ------- --------  --------- --------- + --------- ---------  ----+----
  24.000  23.650  -94.930  4.757E+00 4.669E+18 | 4.422E+00 4.340E+18  H2O |  O3
6398.682  23.791           1.746E-01 1.714E+17 | 1.738E-02 1.706E+16  N2O |  CO
   3480.0                  1.379E+00 1.354E+18 | 3.852E+02 3.780E+20  CH4 | CO2
                           7.808E+05 7.663E+23 | 2.095E+05 2.056E+23   N2 |  O2
                           0.000E+00 0.000E+00 | 9.340E+03 9.167E+21    O |  Ar
                           5.200E+00 5.103E+18 | 0.000E+00 0.000E+00   He |   H
                           0.000E+00 0.000E+00 | MW=28.966 9.815E+23    N | Tot
-------- ------- --------  --------- --------- + --------- ---------  ----+----
  22.000  24.050  -93.730  4.350E+00 6.028E+18 | 2.790E+00 3.867E+18  H2O |  O3
6396.571  24.193           1.930E-01 2.675E+17 | 1.527E-02 2.116E+16  N2O |  CO
   3540.0                  1.592E+00 2.206E+18 | 3.852E+02 5.338E+20  CH4 | CO2
                           7.808E+05 1.082E+24 | 2.095E+05 2.903E+23   N2 |  O2
                           0.000E+00 0.000E+00 | 9.340E+03 1.294E+22    O |  Ar
                           5.200E+00 7.206E+18 | 0.000E+00 0.000E+00   He |   H
                           0.000E+00 0.000E+00 | MW=28.966 1.386E+24    N | Tot
-------- ------- --------  --------- --------- + --------- ---------  ----+----
  20.000  24.450  -92.530  3.837E+00 7.597E+18 | 1.770E+00 3.505E+18  H2O |  O3
6394.458  24.595           2.307E-01 4.568E+17 | 1.651E-02 3.269E+16  N2O |  CO
   3600.0                  1.787E+00 3.538E+18 | 3.852E+02 7.626E+20  CH4 | CO2
                           7.808E+05 1.546E+24 | 2.095E+05 4.147E+23   N2 |  O2
                           0.000E+00 0.000E+00 | 9.340E+03 1.849E+22    O |  Ar
                           5.200E+00 1.029E+19 | 0.000E+00 0.000E+00   He |   H
                           0.000E+00 0.000E+00 | MW=28.966 1.980E+24    N | Tot
-------- ------- --------  --------- --------- + --------- ---------  ----+----
  18.000  24.850  -91.330  3.109E+00 8.771E+18 | 7.675E-01 2.166E+18  H2O |  O3
6392.345  24.997           2.737E-01 7.722E+17 | 2.445E-02 6.900E+16  N2O |  CO
   3660.0                  1.916E+00 5.405E+18 | 3.852E+02 1.087E+21  CH4 | CO2
                           7.808E+05 2.203E+24 | 2.095E+05 5.910E+23   N2 |  O2
                           0.000E+00 0.000E+00 | 9.340E+03 2.635E+22    O |  Ar
                           5.200E+00 1.467E+19 | 0.000E+00 0.000E+00   He |   H
                           0.000E+00 0.000E+00 | MW=28.966 2.822E+24    N | Tot
-------- ------- --------  --------- --------- + --------- ---------  ----+----
  16.000  25.250  -90.130  2.788E+00 1.090E+19 | 2.909E-01 1.138E+18  H2O |  O3
6390.230  25.398           3.056E-01 1.195E+18 | 3.811E-02 1.490E+17  N2O |  CO
   3720.0                  1.996E+00 7.808E+18 | 3.852E+02 1.506E+21  CH4 | CO2
                           7.808E+05 3.054E+24 | 2.095E+05 8.192E+23   N2 |  O2
                           0.000E+00 0.000E+00 | 9.340E+03 3.653E+22    O |  Ar
                           5.200E+00 2.034E+19 | 0.000E+00 0.000E+00   He |   H
                           0.000E+00 0.000E+00 | MW=28.966 3.911E+24    N | Tot
-------- ------- --------  --------- --------- + --------- ---------  ----+----
  14.000  25.650  -88.930  4.643E+00 2.440E+19 | 2.188E-01 1.150E+18  H2O |  O3
6388.114  25.800           3.212E-01 1.688E+18 | 6.244E-02 3.282E+17  N2O |  CO
   3780.0                  2.064E+00 1.085E+19 | 3.852E+02 2.025E+21  CH4 | CO2
                           7.808E+05 4.104E+24 | 2.095E+05 1.101E+24   N2 |  O2
                           0.000E+00 0.000E+00 | 9.340E+03 4.909E+22    O |  Ar
                           5.200E+00 2.733E+19 | 0.000E+00 0.000E+00   He |   H
                           0.000E+00 0.000E+00 | MW=28.966 5.256E+24    N | Tot
-------- ------- --------  --------- --------- + --------- ---------  ----+----
  12.000  26.050  -87.730  1.576E+01 1.084E+20 | 1.616E-01 1.112E+18  H2O |  O3
6385.996  26.202           3.336E-01 2.295E+18 | 9.695E-02 6.671E+17  N2O |  CO
   3840.0                  2.116E+00 1.456E+19 | 3.852E+02 2.650E+21  CH4 | CO2
                           7.808E+05 5.372E+24 | 2.095E+05 1.441E+24   N2 |  O2
                           0.000E+00 0.000E+00 | 9.340E+03 6.426E+22    O |  Ar
                           5.200E+00 3.578E+19 | 0.000E+00 0.000E+00   He |   H
                           0.000E+00 0.000E+00 | MW=28.966 6.881E+24    N | Tot
-------- ------- --------  --------- --------- + --------- ---------  ----+----
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  10.000  26.450  -86.530  1.562E+02 1.374E+21 | 1.004E-01 8.825E+17  H2O |  O3
6383.877  26.604           3.455E-01 3.037E+18 | 1.236E-01 1.087E+18  N2O |  CO
  3900.0                   2.174E+00 1.911E+19 | 3.851E+02 3.386E+21  CH4 | CO2
                           7.807E+05 6.863E+24 | 2.094E+05 1.841E+24   N2 |  O2
                           0.000E+00 0.000E+00 | 9.338E+03 8.210E+22    O |  Ar
                           5.199E+00 4.571E+19 | 0.000E+00 0.000E+00   He |   H
                           0.000E+00 0.000E+00 | MW=28.964 8.791E+24    N | Tot
-------- ------- --------  --------- --------- + --------- ---------  ----+----
   8.000  26.850  -85.330  5.971E+02 6.560E+21 | 6.464E-02 7.102E+17  H2O |  O3
6381.757  27.005           3.509E-01 3.855E+18 | 1.476E-01 1.622E+18  N2O |  CO
  3960.0                   2.206E+00 2.424E+19 | 3.849E+02 4.229E+21  CH4 | CO2
                           7.803E+05 8.573E+24 | 2.093E+05 2.300E+24   N2 |  O2
                           0.000E+00 0.000E+00 | 9.334E+03 1.026E+23    O |  Ar
                           5.197E+00 5.710E+19 | 0.000E+00 0.000E+00   He |   H
                           0.000E+00 0.000E+00 | MW=28.959 1.099E+25    N | Tot
-------- ------- --------  --------- --------- + --------- ---------  ----+----
   6.000  27.250  -84.130  1.256E+03 1.704E+22 | 4.848E-02 6.575E+17  H2O |  O3
6379.636  27.407           3.507E-01 4.756E+18 | 1.599E-01 2.169E+18  N2O |  CO
  4020.0                   2.225E+00 3.018E+19 | 3.847E+02 5.217E+21  CH4 | CO2
                           7.798E+05 1.058E+25 | 2.092E+05 2.837E+24   N2 |  O2
                           0.000E+00 0.000E+00 | 9.328E+03 1.265E+23    O |  Ar
                           5.193E+00 7.043E+19 | 0.000E+00 0.000E+00   He |   H
                           0.000E+00 0.000E+00 | MW=28.952 1.356E+25    N | Tot
-------- ------- --------  --------- --------- + --------- ---------  ----+----
   4.000  27.650  -82.930  2.601E+03 4.352E+22 | 3.715E-02 6.215E+17  H2O |  O3
6377.514  27.808           3.502E-01 5.860E+18 | 1.622E-01 2.714E+18  N2O |  CO
  4080.0                   2.238E+00 3.745E+19 | 3.842E+02 6.428E+21  CH4 | CO2
                           7.788E+05 1.303E+25 | 2.089E+05 3.496E+24   N2 |  O2
                           0.000E+00 0.000E+00 | 9.315E+03 1.559E+23    O |  Ar
                           5.186E+00 8.678E+19 | 0.000E+00 0.000E+00   He |   H
                           0.000E+00 0.000E+00 | MW=28.937 1.673E+25    N | Tot
-------- ------- --------  --------- --------- + --------- ---------  ----+----
   2.000  28.050  -81.730  5.765E+03 1.191E+23 | 3.273E-02 6.760E+17  H2O |  O3
6375.390  28.210           3.491E-01 7.210E+18 | 1.728E-01 3.569E+18  N2O |  CO
  4140.0                   2.231E+00 4.608E+19 | 3.829E+02 7.909E+21  CH4 | CO2
                           7.763E+05 1.603E+25 | 2.083E+05 4.301E+24   N2 |  O2
                           0.000E+00 0.000E+00 | 9.286E+03 1.918E+23    O |  Ar
                           5.170E+00 1.068E+20 | 0.000E+00 0.000E+00   He |   H
                           0.000E+00 0.000E+00 | MW=28.903 2.065E+25    N | Tot
-------- ------- --------  --------- --------- + --------- ---------  ----+----
    .000  28.450  -80.530  1.697E+04 4.305E+23 | 2.980E-02 7.559E+17  H2O |  O3
6373.265  28.611           3.452E-01 8.755E+18 | 1.830E-01 4.643E+18  N2O |  CO
  4200.0                   2.206E+00 5.596E+19 | 3.786E+02 9.604E+21  CH4 | CO2
                           7.676E+05 1.947E+25 | 2.059E+05 5.223E+24   N2 |  O2
                           0.000E+00 0.000E+00 | 9.181E+03 2.329E+23    O |  Ar
                           5.112E+00 1.297E+20 | 0.000E+00 0.000E+00   He |   H
                           0.000E+00 0.000E+00 | MW=28.780 2.537E+25    N | Tot
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E.3 Sample Special Output File Produced by Input File of Appendix D

Time	Hgtkm	GeocenLat	Lon(East)	DensMean	PresMean	Tmean	EWmean	NSmean	DensPert	PresPert	Tpert	EWpert	Nspert	Dpert%	Ppert%	SDden%	SDprs%	SDtemK	SDuwnd	SDvwnd	Wpert	Sev
.00	140.000	.45000	-164.53000	4.4055E-09	9.9645E-04	690.23	20.44	.31	4.7668E-09	1.0166E-03	632.37	91.51	-15.14	8.20	2.02	7.20	12.50	100.77	69.00	69.00	-3.46	0
60.00	138.000	.85000	-163.33000	5.0214E-09	1.0849E-03	662.03	17.48	.50	5.1314E-09	1.1209E-03	676.10	61.54	-20.51	2.19	3.32	7.27	13.20	101.78	69.35	69.26	9.14	0
120.00	136.000	1.25000	-162.13000	5.7637E-09	1.1861E-03	633.20	14.01	.59	5.8194E-09	1.2511E-03	666.60	52.74	-38.96	.97	5.48	7.35	13.86	102.02	69.70	69.52	9.58	0
180.00	134.000	1.65000	-160.93000	6.6667E-09	1.3026E-03	603.80	10.09	.58	6.6687E-09	1.4136E-03	661.49	35.60	15.81	.03	8.52	7.42	14.49	101.53	70.04	69.78	9.50	0
240.00	132.000	2.05000	-159.73000	7.7770E-09	1.4381E-03	573.92	5.72	.52	7.9878E-09	1.6116E-03	616.97	-9.88	13.90	2.71	12.07	7.49	15.09	100.39	70.38	70.05	8.09	0
300.00	130.000	2.45000	-158.53000	9.1578E-09	1.5969E-03	543.64	.97	.40	9.1526E-09	1.8796E-03	658.98	1.42	6.42	-.06	17.70	7.56	15.67	98.64	70.71	70.32	7.44	0
360.00	128.000	2.85000	-157.33000	1.0896E-08	1.7850E-03	513.08	-4.04	.25	1.0321E-08	2.1238E-03	674.77	-28.11	-50.00	-5.28	18.98	7.63	16.23	96.32	71.03	70.60	6.81	0
420.00	126.000	3.25000	-156.13000	1.3116E-08	2.0103E-03	482.33	-9.15	.10	1.1718E-08	2.4243E-03	691.98	13.67	-31.93	-10.66	20.59	7.70	16.77	93.48	71.35	70.87	3.64	0
480.00	124.000	3.65000	-154.93000	1.5992E-08	2.2835E-03	451.51	-14.19	-.04	1.6290E-08	2.7221E-03	496.66	-44.46	-69.61	1.86	19.21	7.77	17.30	90.17	71.67	71.15	3.19	0
540.00	122.000	4.05000	-153.73000	1.9774E-08	2.6192E-03	420.96	-18.96	-.16	1.9255E-08	3.1559E-03	505.66	-28.93	-99.36	-2.62	20.49	7.83	17.81	86.48	71.97	71.44	-.87	0
600.00	120.000	4.45000	-152.53000	2.4811E-08	3.0378E-03	391.14	-23.27	-.25	2.2514E-08	3.7912E-03	558.65	-77.28	-43.24	-9.26	24.80	7.90	18.30	82.53	72.28	71.72	5.80	0
660.00	118.000	4.85000	-151.33000	3.1542E-08	3.5582E-03	362.27	-26.54	-.35	2.7376E-08	4.4335E-03	530.27	-44.05	6.91	-13.21	24.60	8.71	17.79	71.77	72.54	72.02	-1.82	0
720.00	116.000	5.25000	-150.13000	4.0623E-08	4.2069E-03	334.28	-28.13	-.47	3.6972E-08	5.2022E-03	449.40	-39.26	-56.36	-8.99	23.66	9.45	17.27	61.61	72.79	72.33	2.16	0
780.00	114.000	5.65000	-148.93000	5.3196E-08	5.0370E-03	307.30	-27.95	-.64	4.5546E-08	5.9667E-03	408.68	-48.71	-48.22	-14.38	18.46	10.21	16.77	52.47	73.03	72.64	-2.25	0
840.00	112.000	6.05000	-147.73000	7.1143E-08	6.1338E-03	281.47	-26.01	-.90	5.7330E-08	6.9631E-03	369.24	-72.04	57.72	-19.42	13.52	10.98	16.29	44.33	73.25	72.95	.23	0
900.00	110.000	6.45000	-146.53000	9.7904E-08	7.6364E-03	256.31	-22.71	-1.27	9.0764E-08	8.5660E-03	282.49	-55.64	18.25	-7.29	12.17	11.70	15.80	36.65	73.46	73.25	1.51	0
960.00	108.000	6.85000	-145.33000	1.3669E-07	9.7571E-03	236.08	-17.99	-1.77	1.1376E-07	1.0714E-02	280.93	-24.21	-14.92	-16.78	9.81	12.45	15.29	30.80	73.65	73.58	.98	0
1020.00	106.000	7.25000	-144.13010	1.9552E-07	1.2807E-02	218.13	-12.73	-2.43	1.6986E-07	1.3387E-02	235.49	-3.10	-79.52	-13.13	4.53	13.16	14.77	25.43	73.83	73.91	.72	0
1080.00	104.000	7.65000	-142.93010	2.8393E-07	1.7282E-02	204.10	-8.09	-3.23	2.2320E-07	1.7704E-02	232.72	4.68	-59.18	-21.39	2.45	13.90	14.25	21.04	74.00	74.23	1.39	0
1140.00	102.000	8.05000	-141.73010	4.1385E-07	2.3845E-02	194.53	-4.80	-4.15	2.9297E-07	2.4157E-02	234.83	-4.73	39.05	-29.21	1.31	14.67	13.73	17.54	74.16	74.53	-4.07	0
1200.00	100.000	8.45000	-140.53010	6.0942E-07	3.3513E-02	186.92	-2.74	-5.16	5.4176E-07	3.4133E-02	192.83	-4.55	15.80	-11.10	1.85	15.40	13.20	14.02	74.31	74.85	-9.79	0
1260.00	98.000	8.85000	-139.33010	8.8752E-07	4.7754E-02	183.88	-2.12	-5.96	7.6744E-07	4.7565E-02	192.72	32.12	-12.80	-13.53	-.40	14.76	13.66	14.17	74.66	75.67	-5.60	0
1320.00	96.000	9.25000	-138.13010	1.2906E-06	6.8406E-02	182.10	-2.32	-6.47	1.1466E-06	6.7056E-02	186.67	21.15	16.12	-11.15	-1.97	14.10	14.16	14.39	74.98	76.50	-1.79	0
1380.00	94.000	9.65000	-136.93010	1.8719E-06	9.9068E-02	182.59	-3.63	-6.84	1.7045E-06	9.4266E-02	181.23	-19.97	3.16	-8.94	-4.85	13.45	14.71	14.83	75.29	77.35	-1.49	0
1440.00	92.000	10.05000	-135.73010	2.6950E-06	1.4414E-01	185.12	-5.52	-7.01	2.3931E-06	1.3580E-01	189.79	-14.05	44.80	-11.20	-5.79	12.81	15.29	15.48	75.55	78.31	-3.27	0
1500.00	90.000	10.45000	-134.53010	3.8446E-06	2.0815E-01	188.00	-6.55	-6.73	3.0861E-06	1.8446E-01	203.03	-32.27	21.09	-19.73	-11.38	12.14	15.76	16.14	75.54	79.98	-.38	0
1560.00	88.000	10.85000	-133.33010	5.3673E-06	2.9567E-01	191.50	-3.75	-5.10	4.6157E-06	2.6452E-01	199.07	38.87	35.14	-14.00	-10.53	10.18	13.11	13.97	66.08	67.20	5.90	0
1620.00	86.000	11.25000	-132.13010	7.4491E-06	4.1743E-01	195.01	-.93	-3.61	7.1436E-06	3.8799E-01	191.61	61.01	-36.58	-4.10	-7.05	7.71	9.84	11.20	55.48	50.15	-2.96	0
1680.00	84.000	11.65000	-130.93010	1.0266E-05	5.8439E-01	198.22	1.60	-2.90	.7764E-06	5.4975E-01	198.77	58.14	-8.36	-4.77	-5.93	5.86	7.33	9.13	47.59	36.31	-4.32	0
1740.00	82.000	12.05000	-129.73010	1.4068E-05	8.1207E-01	201.03	4.13	-2.98	1.3681E-05	7.6720E-01	198.91	53.73	-11.46	-2.75	-5.52	5.34	6.51	8.50	43.52	31.92	-5.34	0
1800.00	80.000	12.45000	-128.53010	1.9203E-05	1.1235E+00	203.76	7.07	-3.19	1.9118E-05	1.0733E+00	199.22	16.06	-4.84	-.45	-4.46	4.76	5.58	7.79	39.10	26.93	-4.54	0
1860.00	78.000	12.85000	-127.33010	2.6179E-05	1.5487E+00	206.03	13.56	-1.05	2.6742E-05	1.4788E+00	196.77	12.74	9.29	2.15	-4.51	4.68	5.54	7.83	38.03	25.76	.91	0
1920.00	76.000	13.25000	-126.13010	3.5588E-05	2.1284E+00	208.28	20.06	.84	3.7198E-05	2.0687E+00	198.25	23.67	19.23	4.52	-2.81	4.59	5.51	7.87	36.86	24.57	-.21	0
1980.00	74.000	13.65000	-124.93010	4.8046E-05	2.9186E+00	211.57	25.43	1.51	4.8157E-05	2.8125E+00	209.02	28.80	27.90	.23	-3.63	4.43	5.26	7.63	35.54	22.44	1.61	0
2040.00	72.000	14.05000	-123.73010	6.4285E-05	3.9834E+00	215.86	29.72	1.14	6.5638E-05	3.8538E+00	209.84	42.68	22.73	2.11	-3.25	4.17	4.73	7.05	34.17	18.99	1.91	0
2100.00	70.000	14.45000	-122.53010	8.5552E-05	5.4040E+00	220.11	34.07	.81	8.3971E-05	5.2128E+00	221.60	59.94	8.28	-1.85	-3.54	3.88	4.13	6.35	32.80	14.74	-.26	0
2160.00	68.000	14.84999	-121.33010	1.1209E-04	7.2811E+00	226.37	35.10	.59	1.1194E-04	6.9984E+00	223.52	71.05	4.49	-.13	-3.88	4.00	4.04	6.31	30.37	15.01	.61	0
2220.00	66.000	15.24999	-120.13010	1.4583E-04	9.7301E+00	232.53	36.27	.39	1.4628E-04	9.2604E+00	226.56	62.31	2.86	.31	-4.83	4.07	3.93	6.26	27.77	15.31	-1.14	0
2280.00	64.000	15.64999	-118.93010	1.8903E-04	1.2920E+01	238.16	36.26	.43	1.8275E-04	1.2181E+01	239.65	39.17	11.00	-3.32	-5.72	4.20	4.10	6.14	26.03	15.04	.88	0
2340.00	62.000	16.04999	-117.73010	2.4440E-04	1.7070E+01	243.32	35.09	.53	2.3250E-04	1.5836E+01	246.80	53.91	15.54	-4.87	-7.23	4.41	4.54	5.92	25.28	14.16	-.67	0
2400.00	60.000	16.44999	-116.53010	3.1444E-04	2.2427E+01	248.43	34.01	.61	3.1694E-04	2.0929E+01	241.12	66.07	11.58	.80	-6.68	4.61	4.94	5.63	24.44	13.20	1.55	0
2460.00	58.000	16.84999	-115.33010	4.0259E-04	2.9288E+01	253.49	29.51	.18	4.2415E-04	2.7817E+01	238.49	66.95	2.15	5.35	-5.02	4.40	4.74	5.51	24.33	12.73	2.95	0
2520.00	56.000	17.24999	-114.13010	5.1291E-04	3.8052E+01	258.59	25.04	-.25	5.5072E-04	3.6720E+01	241.72	37.32	-5.41	7.37	-3.50	4.20	4.55	5.40	24.25	12.24	-.53	0
2580.00	54.000	17.64999	-112.93010	6.5349E-04	4.9199E+01	262.42	20.98	-.50	6.6540E-04	4.7283E+01	258.46	36.97	12.01	1.82	-3.89	4.01	4.37	5.30	24.36	11.93	-2.30	0
2640.00	52.000	18.04999	-111.73010	8.3410E-04	6.3428E+01	265.00	17.28	-.58	8.6446E-04	6.1056E+01	256.15	19.52	12.39	3.64	-3.74	3.82	4.19	5.18	24.66	11.85	-.69	0
2700.00	50.000	18.44999	-110.53010	1.0619E-03	8.1578E+01	267.67	13.52	-.62	1.1182E-03	7.9207E+01	256.02	36.84	-1.01	5.30	-2.91	3.62	4.00	5.01	24.98	11.78	-.71	0
2760.00	48.000	18.84999	-109.33010	1.3681E-03	1.0476E+02	266.76	13.65	-.70	1.4050E-03	1.0154E+02	260.98	5.14	.79	2.69	-3.07	3.53	3.81	5.09	24.41	11.06	.27	0
2820.00	46.000	19.24999	-108.13010	1.7638E-03	1.3463E+02	265.90	13.59	-.74	1.8145E-03	1.3057E+02	259.05	36.36	.23	2.87	-3.02	3.44	3.61	5.19	23.83	10.29	.22	0

Sample Special Output File Produced by Input File of Appendix D (Continued)

Time	Hgtkm	GeocenLat	Lon(East)	DensMean	PresMean	Tmean	EWmean	NSmean	DensPert	PresPert	Tpert	EWpert	Nspert	Dpert%	Ppert%	SDden%	SDprs%	SDtemK	SDuwnd	SDvwnd	Wpert	Sev
2880.00	44.000	19.64999	-106.93010	2.2911E-03	1.7329E+02	263.47	13.94	-.79	2.3825E-03	1.6877E+02	254.08	35.13	-2.21	3.99	-2.61	3.29	3.41	5.18	23.08	9.43	-.39	0
2940.00	42.000	20.04999	-105.73010	3.0066E-03	2.2388E+02	259.38	14.66	-.84	3.1083E-03	2.1905E+02	252.18	16.81	4.73	3.38	-2.15	3.06	3.21	5.04	22.11	8.45	.97	0
3000.00	40.000	20.44999	-104.53020	3.9614E-03	2.9021E+02	255.19	14.94	-.92	4.0049E-03	2.8332E+02	252.67	46.80	12.33	1.10	-2.37	2.83	3.03	4.93	20.97	7.41	.41	0
3060.00	38.000	20.84999	-103.33020	5.2875E-03	3.7872E+02	249.51	13.94	-.97	5.3506E-03	3.6963E+02	245.91	19.71	6.15	1.19	-2.40	2.67	2.83	4.96	19.85	7.11	.58	0
3120.00	36.000	21.24999	-102.13020	7.1057E-03	4.9732E+02	243.81	12.82	-1.04	7.2185E-03	4.8501E+02	238.28	12.31	-.29	1.59	-2.47	2.49	2.60	4.95	18.64	6.76	-.31	0
3180.00	34.000	21.64999	-100.93020	9.6138E-03	6.5752E+02	238.30	12.08	-.87	9.5204E-03	6.4197E+02	238.51	37.60	5.15	-.97	-2.36	2.30	2.38	4.76	17.13	6.26	-.09	0
3240.00	32.000	22.04999	-99.73016	1.3090E-02	8.7510E+02	233.04	11.81	-.53	1.2965E-02	8.5474E+02	232.68	25.60	3.79	-.96	-2.33	2.08	2.16	4.41	15.31	5.55	.51	0
3300.00	30.000	22.44999	-98.53017	1.7945E-02	1.1723E+03	227.84	11.24	-.25	1.7715E-02	1.1498E+03	228.49	22.25	2.73	-1.28	-1.92	1.84	1.91	4.05	13.26	4.71	.32	0
3360.00	28.000	22.84999	-97.33017	2.4625E-02	1.5818E+03	223.95	9.69	-.58	2.4421E-02	1.5545E+03	223.62	19.41	7.07	-.83	-1.72	1.71	1.73	3.58	11.94	4.16	.79	0
3420.00	26.000	23.24999	-96.13017	3.3982E-02	2.1453E+03	220.01	8.04	-.67	3.4236E-02	2.1248E+03	217.52	5.35	6.51	.75	-.96	1.56	1.54	3.11	10.33	3.55	.58	0
3480.00	24.000	23.64999	-94.93018	4.7210E-02	2.9267E+03	215.99	7.13	.34	4.7561E-02	2.8965E+03	213.54	11.65	2.08	.74	-1.03	1.42	1.74	2.77	8.45	3.63	.76	0
3540.00	22.000	24.04999	-93.73018	6.6657E-02	4.0354E+03	210.91	7.57	1.57	6.6628E-02	4.0062E+03	209.86	7.76	3.87	-.04	-.72	1.41	1.27	2.76	6.94	4.13	.77	0
3600.00	20.000	24.44999	-92.53018	9.5223E-02	5.6081E+03	205.16	10.01	2.60	9.6301E-02	5.5768E+03	201.58	18.42	.77	1.13	-.56	1.37	.59	2.77	6.23	4.76	-.49	0
3660.00	18.000	24.84999	-91.33018	1.3571E-01	7.8470E+03	201.44	16.37	3.68	1.3631E-01	7.8284E+03	199.85	29.31	11.29	.44	-.24	1.37	.69	2.73	7.03	5.73	.30	0
3720.00	16.000	25.24998	-90.13019	1.8810E-01	1.0980E+04	203.36	25.31	5.53	1.8820E-01	1.0962E+04	202.52	38.63	12.35	.05	-.17	1.27	.92	2.60	8.91	7.28	-1.18	0
3780.00	14.000	25.64998	-88.93019	2.5280E-01	1.5226E+04	209.82	33.88	7.23	2.4955E-01	1.5214E+04	211.68	34.33	1.67	-1.29	-.08	1.07	1.13	2.24	10.71	9.50	-.22	0
3840.00	12.000	26.04998	-87.73019	3.3093E-01	2.0861E+04	219.60	35.66	7.45	3.2404E-01	2.0892E+04	223.49	47.35	7.00	-2.08	.15	1.14	1.16	2.53	11.76	11.75	-.33	0
3900.00	10.000	26.44998	-86.53020	4.2280E-01	2.8168E+04	232.07	30.93	5.92	4.1611E-01	2.8261E+04	235.23	51.12	7.26	-1.58	.33	.89	1.08	2.06	11.35	11.51	.31	0
3960.00	8.000	26.84998	-85.33020	5.2830E-01	3.7368E+04	246.35	24.66	4.34	5.2389E-01	3.7566E+04	248.44	34.14	-11.99	-.84	.53	.90	.91	2.17	9.87	10.09	.92	0
4020.00	6.000	27.24998	-84.13020	6.5194E-01	4.8827E+04	260.79	18.53	2.98	6.5059E-01	4.9215E+04	262.44	14.12	-8.54	-.21	.79	.92	.73	2.36	8.33	8.46	-.06	0
4080.00	4.000	27.64998	-82.93021	8.0394E-01	6.2943E+04	272.48	12.92	1.90	8.0126E-01	6.3371E+04	274.63	6.78	-5.90	-.33	.68	.92	.59	2.45	7.37	6.81	.24	0
4140.00	2.000	28.04998	-81.73021	9.9121E-01	8.0387E+04	281.91	6.59	1.18	9.9291E-01	8.0888E+04	282.88	-.24	-6.36	.17	.62	1.24	.46	3.15	6.54	5.73	-1.27	0
4200.00	.000	28.44998	-80.53021	1.2123E+00	1.0209E+05	291.53	.79	-.57	1.2101E+00	1.0258E+05	293.36	-10.09	-7.04	-.18	.48	1.16	.46	3.23	4.37	4.33	-.87	0

APPENDIX F—PARAMETERS AVAILABLE FOR SPECIAL OUTPUT

Following is a listing of the section of GRAM where the "Special Output" can be prepared and generated. This identifies logical places to do computations of special variables (e.g. the examples sound speed, csp, at line ATMD660, pressure scale height, Hgtp, and density scale height, Hgtd, at line ATMD 662 and 663) or to do units conversions (e.g., multiplying by conversion factors). Comments in this code section also provide lists of the names of the variables that are available for writing to the Special Output. An example of a write statement and user-provided format for writing to the Special Output is given on lines ATMD766 through ATMD769.

Another feature is the capability to write surface data values to the special output file. Surface data parameter identifiers are discussed on lines ATMD744-ATMD757.

```
C.....  "Special" output option section                                 ATMD649
        If (iopp.ne.0) Then                                             ATMD650
C       EXAMPLES OF SPECIALLY COMPUTED OUTPUT:                          ATMD651
C.....  Wind speed (m/s) and direction (meteorological convention) from ATMD652
C       mean winds                                                      ATMD653
        WndSpd = Sqrt(ugh**2 + vgh**2)                                  ATMD654
        Wnddir = 180.0                                                  ATMD655
        If (Abs(ugh).gt.0.0.and.Abs(vgh).gt.0.0)WndDir = 180.0*(1.0+    ATMD656
     &    Atan2(ugh,vgh)/ 3.14159265)                                   ATMD657
C.....  Sound speed (m/s) from pressure (N/m**2) and density (kg/m**3)  ATMD658
C       (Assume mean values and ratio of specific heats = 7/5)          ATMD659
        csp = Sqrt(1.4*pgh/dgh)                                         ATMD660
C.....  Pressure scale height (m), density scale height (m)             ATMD661
        Hgtp = pgh/(dgh*g)                                              ATMD662
        If (h.le.hj1)Then                                               ATMD663
          Hgtd = Hgtp/(1. + Hgtp*dtz/tgh)                               ATMD664
        Else                                                            ATMD665
          Hgtd = Hgtp/(1. + Hgtp*dtz/tgh - Hgtp*dmdz/wtmol)             ATMD666
        Endif                                                           ATMD667
C.....  Mean free path (m)  (assume mean values of pressure and temp.)  ATMD668
        mfpath = 7.071E17/(0.424*totnd)                                 ATMD669
C.....  Gas constant (N m kmol**-1 K**-1) and specific heat at constant  ATMD670
C       pressure (N m kmol**-1 K**-1)                                   ATMD671
C       (Assume mean values and ratio of specific heats = 7/5)          ATMD672
        gasconst = 8314.32/mwnd                                         ATMD673
        cpmn = (1.4/0.4)*gasconst                                       ATMD674
C.....  Other variables that are functions of pressure, density,        ATMD675
C       temperature, wind and/or moisture, can be calculated here.      ATMD676
C       Some such variables are: coefficient of viscosity, kinematic    ATMD677
C       viscosity, thermal conduction coefficient, potential            ATMD678
C       temperature, equivalent potential temperature, etc.             ATMD679
C                                                                       ATMD680
C.....  Any change of units for writing to "special" output file can    ATMD681
C       be done here (e.g. MKS to English units, etc.)                  ATMD682
C                                                                       ATMD683
C....   **** To print out header information, refer to the section      ATMD684
C       **** near format label 954 in init subroutine of initial_E07.f. ATMD685
C.......................................................................ATMD686
```

```
C                                                                    *ATMD687
C     As an aid to the user, the following tables give the names of    *ATMD688
C     the variables that are available for output:                      *ATMD689
C                                                                    *ATMD690
C.... Position and time parameters                                   *ATMD691
C     ----------------------------                                   *ATMD692
C      h -      Geocentric Height (km) above WGS84 Reference Ellipsoid *ATMD693
C      Rlocal - Radius from Earth center (km) (Earth radius plus h)    *ATMD693a
C      phi -   Geocentric Latitude (deg)                              *ATMD694
C      GdLat - Geodetic Latitude (deg)                                *ATMD695
C      thet -  Longitude (deg), East(+) West(-)                       *ATMD696
C      elt -   Elapsed Time (sec)                                     *ATMD697
C                                                                    *ATMD698
C.... Thermodynamic, wind and moisture parameters (on standard output) *ATMD699
C     ----------------------------------------------------------------- *ATMD700
C                                                                    *ATMD701
C           Pressure    Density/  Temperature   E-W   N-S   Vert.      *ATMD702
C           /Vap. Pr    Vap.Dens.   /Dewpt.     Wind  Wind  Wind(m/s)  *ATMD703
C           (Nt/m**2)   (kg/m**3)    (K)        (m/s) (m/s) /RH(%)     *ATMD704
C           ---------   --------- -----------   ----- ----- -----      *ATMD705
C*Mean         pgh         dgh        tgh         ugh   vgh   wgh      *ATMD706
C                                                                    *ATMD706a
C*Mean-76      pghp (%)    dghp (%)   tghp (%)    n/a   n/a   n/a      *ATMD707
C                                                                    *ATMD707a
C*Small-Scale                                                        *ATMD708
C Perturbation prhs (%)    drhs (%)   trhs (%)    urhs  vrhs  n/a      *ATMD709
C                                                                    *ATMD709a
C*Small-Scale                                                        *ATMD710
C Stand. Dev.  sphs (%)    sdhs (%)   sths (%)    suhs  svhs  n/a      *ATMD711
C                                                                    *ATMD711a
C*Large-Scale                                                        *ATMD712
C Perturbation prhl (%)    drhl (%)   trhl (%)    urhl  vrhl  n/a      *ATMD713
C                                                                    *ATMD713a
C*Large-Scale                                                        *ATMD714
C Stand. Dev.  sphl (%)    sdhl (%)   sthl (%)    suhl  svhl  n/a      *ATMD715
C                                                                    *ATMD715a
C*Total                                                              *ATMD716
C Perturbation prh  (%)    drh  (%)   trh  (%)    urh   vrh   wrh      *ATMD717
C                                                                    *ATMD717a
C*Total Stand.                                                       *ATMD718
C Deviation    sph  (%)    sdh  (%)   sth  (%)    suh   svh   swh      *ATMD719
C                                                                    *ATMD719a
C*Total=Mean+                                                        *ATMD720
C Perturbation ph          dh         th          uh    vh    wh       *ATMD721
C                                                                    *ATMD721a
C*Total-US76   php  (%)    dhp  (%)   thp  (%)    n/a   n/a   n/a      *ATMD722
C                                                                    *ATMD722a
C*Mean H2O     eofT        rhov       tdgh        n/a   n/a   rhp      *ATMD723
C                                                                    *ATMD723a
C*Stand. Dev.                                                        *ATMD724
C H2O          seofT       srhov      stdgh       n/a   n/a  srhp      *ATMD725
C                                                                    *ATMD726
C....   Species concentration parameters (on species output)          *ATMD727
C       ---------------------------------------------------          *ATMD728
C                                                                    *ATMD729
C           H2O  O3   N2O  CO   CH4  CO2   N2  O2   O  Ar  He  H   N   *ATMD730
C           ---  --   ---  --   ---  ---   --  --   -  --  --  -   -   *ATMD731
C Concen-   ppmh2o    ppmn2o    ppmch4     ppmn2    ppmo   ppmhe  ppmn *ATMD732
C tration       ppmo3     ppmco     ppmco2    ppmo2   ppmar   ppmh     *ATMD733
C -----------------------------------------------------------------   *ATMD734
```

```
C Number    h2ond     n2ond     ch4nd      n2nd     ond    hend   nnd  *ATMD735
C Density        o3nd      cond      co2nd     o2nd    arnd    hnd     *ATMD736
C                                                                      *ATMD737
C       Mean molecular weight=mwnd        total number densty=totnd    *ATMD738
C                                                                      *ATMD739
C                                                                      *ATMD740
C....   Surface data (passed from Subroutine guamod, via Common        *ATMD741
C       Block srfdat)                                                  *ATMD742
C       -------------------------------------------------------        *ATMD743
C       psrf   = surface pressure (N/m**2)                             *ATMD744
C       dsrf   = surface density (kg/m**3)                             *ATMD745
C       tsrf   = surface temperature (K)                               *ATMD746
C       usrf   = surface Eastward wind component (m/s)                 *ATMD747
C       vsrf   = surface Northward wind component (m/s)                *ATMD748
C       hsrf   = height of surface (m, above sea level)                *ATMD749
C       tdsrf  = surface dewpoint temperature (K)                      *ATMD750
C       spsrf  = standard deviation of surface pressure (N/m**2)       *ATMD751
C       sdsrf  = standard deviation of surface density (kg/m**3)       *ATMD752
C       stsrf  = standard deviation of surface temperature (K)         *ATMD753
C       susrf  = standard deviation of surface Eastward wind (m/s)     *ATMD754
C       svsrf  = standard deviation of surface Northward wind (m/s)    *ATMD755
C       shsrf  = std. dev. (uncertainty) of surf. hgt (m, from spsrf)  *ATMD756
C       stdsrf = standard deviation of surface dewpoint temp. (K)      *ATMD757
C                                                                      *ATMD758
C.....At this point, the user is invited to insert whatever output     *ATMD759
C     parameters (in whatever format) are desired for the “special”    *ATMD760
C     output instead of the Write and Format statements below. Any new *ATMD761
C     variables introduced must be declared at the beginning of the    *ATMD762
C     atmod subroutine.                                                *ATMD763
C                                                                      *ATMD764
      isev = 0                                                          ATMD764a
      If (densfact.gt.1.0)isev = 1                                      ATMD764b
C...  Release code version of write to special output file              ATMD765
        Write(iopp,9000)elt,h,phi,thet,dgh,pgh,tgh,ugh,vgh,dh,ph,th,uh, ATMD766
     &    vh,drh,prh,sdh,sph,0.01*sth*tgh,suh,svh,wh,isev               ATMD767
 9000   Format(F10.2,F9.3,F10.5,F11.5,1p,2E11.4,0p,F8.2,2F8.2,1p,       ATMD768
     &    2E11.4,0p,F8.2,2F8.2,8F7.2,I3)                                ATMD769
C                                                                       ATMD769
C...  Samples of how to change units:                                   ATMD770
C                                                                       ATMD771
C     Change pressure and standard deviation to millibars               ATMD772
C     pgh = pgh/100.                                                    ATMD773
C     sph = pgh*sph/100.                                                ATMD774
C     ph =  ph/100.                                                     ATMD775
C...  Change density and standard deviation to gm/m**3                  ATMD776
C     dgh = dgh*1000.                                                   ATMD777
C     sdh = dgh*sdh/100.                                                ATMD778
C     dh = dh*1000.                                                     ATMD779
C...  Change temperature and standard deviation to deg C                ATMD780
C     sth = tgh*sth/100.                                                ATMD781
C     tgh = tgh - 273.15                                                ATMD782
C     th = th - 273.15                                                  ATMD783
C                                                                       ATMD784
C...  Samples of some other write statements and formats for special    ATMD785
C     output file, including some changes of units (e.g. dividing       ATMD786
C     height by 0.3048 to convert to k-feet), dividing mission          ATMD787
C     elapsed time by 3600. to convert to hours)                        ATMD788
C                                                                       ATMD789
C     Write(iopp,9000)h,mfpath,dgh,tgh                                  ATMD789a
C9000 Format(F6.1,1p,2E11.3,0p,F7.1)                                    ATMD789b
```

```
C     Write(iopp,9000)h,suh,svh,sdh,urh,vrh,drh                         ATMD789c
C9000 Format(F6.2,6F8.2)                                                 ATMD789d
C...  Write(iopp,9000)elt/3600.,h/0.3048,prhs,prhl,prh,drhs,drhl,drh,   ATMD790
C... &  trhs,trhl,trh,prhs/sphs,drhs/sdhs,trhs/sths                      ATMD791
C9000 Format(2F8.1,12F8.3)                                               ATMD792
C...  Write(iopp,9000)elt/3600.,h/0.3048,pgh,sph,ph,dgh,sdh,dh,tgh,     ATMD793
C... &  sth,th,prhs/sphs,drhs/sdhs,trhs/sths                             ATMD794
C9000 Format(2F8.1,1p,6E10.3,0p,3F10.2,3F8.3)                            ATMD795
C...  Write(iopp,9000)h,sphs/sph,sdhs/sdh,sths/sth,suhs/suh,svhs/svh    ATMD796
C... & sphl/sph,sdhl/sdh,sthl/sth,suhl/suh,svhl/svh,sph,sdh,sth,suh,    ATMD797
C... & svh,suhs                                                          ATMD798
C9000 Format(F7.2,10F6.4,3F7.3,F6.2,2F7.2)                               ATMD799
C...  Write(iopp,9000)elt/3600.,h,uh,vh                                  ATMD800
C9000   Format(F8.1,F8.3,2F8.2)                                          ATMD801
C...  Write(iopp,9000)elt,h,phi,thet,dgh,dghp,sdh,drh,tgh,sth,trh,ugh,   ATMD802
C    &  suh,urh,vgh,svh,vrh                                              ATMD803
C9000 Format(F9.1,F9.3,F8.3,F9.3,1p,E10.3,0p,3F6.1,F7.1,2F6.1,6F7.1)    ATMD804
C                                                                        ATMD805
C.....  The "special" output option Write and Format section ends here. ATMD806
      Endif                                                              ATMD807
C.......................................................................ATMD808
C                                                                        ATMD809
      Return                                                             ATMD810
      End                                                                ATMD811
C-----------------------------------------------------------------------ATMD812
```

Note that the header for the special output is written in the subroutine initial_E07.f. The following code section shows the header that is written for the sample special output list above.

```
C.......................................................................INIT390
      If(iopp.ne.0) Then                                                 INIT391
C.....  This is the header for the "special" output file.  The user     INIT392
C       should insure that the 954 format is compatible with the output INIT393
C       format in subroutine atmod near label number 9000 in the        INIT394
C       models_E07.f file.                                              INIT395
        Write(iopp,954)                                                  INIT396
C                                                                        INIT397
C...  Header format for write statement in normal release code          INIT398
C                                                                        INIT399
 954    Format('      Time    Hgtkm GeocenLat  Lon(East)   DensMean',    INIT400
     &    '   PresMean   Tmean  EWmean  NSmean   DensPert   PresPert ', INIT401
     &    '  Tpert  EWpert  NSpert Dpert% Ppert% SDden% SDprs%',        INIT402
     &    ' SDtemK SDuwnd SDvwnd  Wpert Sev')                            INIT403
```

APPENDIX G—EXAMPLE APPLICATION OF GRAM07 AS SUBROUTINES IN ANOTHER MAIN DRIVER

For many applications, it is desirable to use GRAM07 in the form of subroutines in another program. For example, the main driver program may be a trajectory calculating program, for which GRAM07 provides the atmospheric density and winds used to update the trajectory positions (or to provide the densities and temperatures to compute heat loads, etc.). Several code files are provided that illustrate how to use GRAM as a subroutine in a user-provided trajectory program, and how to implement these new features of the perturbation model. These files include:

gramtraj_E07.f	A subroutine for use in user-provided trajectory program
trajdemo_E07.f	A main driver (replaces gram_E07.f) for use in a simple trajectory demonstration program
trajopts_E07.f	A main driver (replaces gram_E07.f) for use in an example trajectory program that demonstrates several special options of the perturbation model.
multtraj_E07.f	A main driver (replaces gram_E07.f) program that illustrates how to call GRAM07 to evaluate multiple trajectories in one program run, with independent (un-correlated) small-scale correlations between trajectories. Should we include multbody?
trajcalc_E07.f	Subroutines used in these trajectory demonstration programs, illustrating how the users trajectory program should calculate and provide position and velocity information to GRAM.
corrtraj_E07.f	A main driver (replaces gram_E07.f) program illustrating how to call GRAM07 to evaluate multiple profiles in one program run, with small-scale correlations preserved between the profiles.

As an example of how one might use GRAM07 in a user-provided trajectory code, trajdemo_E07.f will be discussed and this program is shown below. As provided, trajdemo is a simple driver, not exercising any of several available GRAM calling options. Programs trajopts_E07.f and multtraj_E07.f illustrate how to call GRAM using these options and could be substituted for trajdemo_E07.f if the additional features are desired. To utilize trajdemo_E07.f in the user's code, it must be compiled and linked with the GRAM routines: gramtraj_E07.f, gramsubs_E07.f, guaca_E07.f, initial_E07.f, MET07prg_E07.f, models_E07.f, random_E07.f, speconc_E07.f, RRAmods_E07.f, MSISsubs_E07.f, HWMsubs_E07.f, and JB2006_E07.f. Certain output parameters are currently passed through the argument list of gramtraj (e.g. mean and perturbed values of density, pressure, temperature and winds; US standard atmosphere values of density, pressure, and temperature). Other atmospheric variables can be added to the argument list by the user. See Appendix F for a description of the output variable names available. As an example of how a double precision trajectory code would be configured, the current argument list variables in gramtraj_E07.f have been made double precision (Real*8). If only single precision is desired, these declarations (and the Dble assignment statements of the argument list variables in gramtraj_E07.f and trajdemo_E07.f) may be modified accordingly. No other modification to gramtraj_E07.f is required and it will automatically call all of the GRAM routines it needs.

Following is a simplified description of the functions required to be performed in the main driver program, as given in the "uncommented" lines of code in trajdemo_E07.f (comment lines, beginning with "C", are not executable).

1. TRJD 34 – 37: Declaration of double precision variables as described above.

2. TRJD 41: Call to a dummy routine (setipos_E07 found in trajcalc_E07.f) that should be replaced with the user's code to provide the initial (starting) time (seconds), initial height (kilometers) above mean sea level or radius if above 6,000 kilometers, initial geocentric latitude (degrees), and initial longitude (degrees).

3. TRJD 43 – 46: Sets "previous" values (used later in the code) to the above initial values.

4. TRJD 57: The parameter *ifirst* is set equal to 1 which will subsequently trigger gramtraj_E07.f to initialize the GRAM model.

5. TRJD 59 – 64: Initial perturbations are set to zero unless over-ridden by values supplied by the user in the input file parameters *initpert*, *rpinit*, *rdinit*, *rtinit*, *ruinit*, *rvinit*, and *rwinit*.

6. TRJD 67 – 70: The first call to gramtraj_E07.f which will initialize the code. The inputs used by the code are *ifirst* (= 1 at this point), initial time *ctime*, initial height *chgt*, initial latitude *clat*, initial longitude *clon*, and the initial user perturbations if any (see 5 above) *ppert, dpert, tpert, upert, vpert, and wpert*.

7. TRJD 75 – 76: Call to a routine (exemplified by dummy routine newpos_E07.f in trajcalc_E07.f) that allows trajdemo_E07.f to compute changes in time and position that it will use later. The call to newpos_E07 here, simply initializes the time and position values.

8. TRJD 80: In preparation for the next call to gramtraj_E07.f, the parameter *ifirst* is set to zero. This will prohibit a reinitialization of GRAM since that was accomplished in 6 above. This line (label 20) also begins the loop over calculated positions and corresponding calculated atmospheric values.

9. TRJD 85 – 86: Here is where newpos_E07 (or its functional equivalent in the user' trajectory code) is called to compute the next time and position along the trajectory.

10. TRJD 91 – 94: The second call to gramtraj_E07.f. Since *ifirst* is now zero, GRAM will take the previous and current time and position and evaluate new mean and pertuebed atmospheric values for the new position. This process continues (by looping back to label 20) until *ifirst* is set to a nonzero value by gramtraj_E07.

11. TRJD 99: If *ifirst* is still equal to zero, the code loops back to line number 20 after which the user should provide a new position from their trajectory code. This looping can continue until the end of the trajectory is reached. At the point, the user should change the value of *ifirst* to trigger a different action. If the user no longer requires additional GRAM values, then setting *ifirst* less than one will send the program to TRJD 120 where the user can end the program or perform additional tasks at his discretion. If the user is performing a Monte Carlo run, then *ifirst* should be set to -1.

12. TRJD 100: If *ifirst* has been set to -1 by gramtraj_E07, for another iteration of a Monte Carlo run, then the user perturbations are set to zero again (TRJD 104 – 109).

13. TRJD 112 – 115: This is a call to gramtraj_E07.f which will utilize the next random number seed and reinitialize GRAM.

14. TRJD 117: A call to dummy routine newpos_E07 that is unnecessary for a user supplied trajectory.

15. TRJD 119: The program is directed back to line 20 to start at the beginning of the trajectory for the next Monte Carlo cycle. After line 20, the user supplies the starting point of the trajectory.

G.1 Listing of Example Main Driver Program (trajdemo_E07.f) Using gramtraj_E07.f as Subroutines

```
C     Example GRAM driver demonstrating how to use gramtraj subroutine  TRJD  1
C                                                                       TRJD  2
C     This example driver should be compiled and linked with;           TRJD  3
C       gramtraj_E07.f - a subroutine that can be used to call GRAM     TRJD  4
C                    from within in the users trajectory code           TRJD  5
C       trajcalc_E07.f - a file containing simple examples of routines  TRJD  6
C                    to initialize trajectory position (setipos) and    TRJD  7
C                    update the trajectory velocity and position        TRJD  8
C                    (newpos)                                           TRJD  9
C       All the other GRAM routines (gramsubs_E07.f, guaca_E07.f,       TRJD 10
C        initial_E07.f, MET07prg_E07.f, models_E07.f, random_E07.f,     TRJD 11
C        speconc_E07.f, RRAmods_E07.f, MSISsubs_E07.f, HWMsubs_E07.f,   TRJD 12
C        and JB2006_E07.f)                                              TRJD 12a
C                                                                       TRJD 13
C     As provided, trajdemo is a "plain vanilla" driver, not exercising TRJD 14
C     any of several available GRAM calling options.  Programs          TRJD 15
C     trajopts_E07.f and multtraj_E07.f illustrate how to call GRAM     TRJD 16
C     using these options.                                              TRJD 17
C                                                                       TRJD 18
C     Certain output parameters are currently passed through the        TRJD 19
C     argument list of gramtraj (e.g. mean and perturbed values of      TRJD 20
C     density, pressure, temperature and winds; US standard             TRJD 21
C     atmosphere values of density, pressure, and temperature).         TRJD 22
C     Other atmospheric variables can be added to the argument list     TRJD 23
C     by the user.  See README files for a description of the output    TRJD 24
C     variable names available .                                        TRJD 25
C                                                                       TRJD 26
C     As an example of how a double precision trajectory code would     TRJD 27
C     be configured, the current argument list variables in gramtraj    TRJD 28
C     have been made double precision (Real*8). If only single          TRJD 29
C     precision is desired, these declarations (and the Dble            TRJD 30
C     assignment statements of the argument list variables in           TRJD 31
C     gramtraj) may be modified accordingly.                            TRJD 32
C                                                                       TRJD 33
      Double Precision ctime,chgt,clat,clon,dctime,dchgt,dclat,dclon,   TRJD 34
     &  dmean,pmean,tmean,umean,vmean,wmean,dpert,ppert,tpert,upert,    TRJD 35
     &  vpert,wpert,dstand,pstand,tstand,                               TRJD 36
     &  ptime,phgt,plat,plon                                            TRJD 37
C                                                                       TRJD 38
C...  Initialize the time (sec) and position (height or radius, km;     TRJD 39
```

```
C     latitude, deg N; longitude, deg E)
      Call setipos_E07(ctime,chgt,clat,clon)
C...  Save current time, position as previous time, position
      ptime = ctime
      phgt = chgt
      plat = clat
      plon = clon
C
C     ifirst is used as a parameter to trigger GRAM initialization
C     (ifirst = 1), and to be used as a return code to trigger any
C     desired actions by the main program.  In this example, ifirst
C     = 0 causes recycle to next position; ifirst = -1 causes
C     re-initialization of position (and velocity) values;
C     ifirst < -1 causes the program to terminate
C
C     Initialize the atmospheric variables with the gramtraj routine
C
      ifirst = 1
C
      ppert = 0.0
      dpert = 0.0
      tpert = 0.0
      upert = 0.0
      vpert = 0.0
      wpert = 0.0
C...  Call to gramtraj for setting initial values, including reading of
C     NAMELIST input file, GUACA data and atmosdat files
      Call gramtraj_E07(ifirst,ctime,chgt,clat,clon,dmean,pmean,tmean,
     & umean,vmean,wmean,dpert,ppert,tpert,upert,vpert,wpert,dstand,
     & pstand,tstand,0,ctime,chgt,clat,clon,1,1,1,phidens,waverand,
     & psmall,dsmall,tsmall,usmall,vsmall,wsmall,AmpFact)
C
C     Initialize the trajectory velocity (or position displacement)
C     values (if initialization is necessary)
C
      Call newpos_E07(ifirst,ptime,phgt,plat,plon,ctime,chgt,clat,clon,
     &  dctime,dchgt,dclat,dclon,0)
C
C     Begin cycle of positions and atmospheric values
C
  20  ifirst = 0
C
C     Update the velocity (or position displacement) values and the
C     time and position values
C
      Call newpos_E07(ifirst,ptime,phgt,plat,plon,ctime,chgt,clat,clon,
     &  dctime,dchgt,dclat,dclon,0)
C
C     Evaluate the atmospheric parameters at the new position
C
C...    Call to gramtraj for next trajectory position
        Call gramtraj_E07(ifirst,ctime,chgt,clat,clon,dmean,pmean,
     &   tmean,umean,vmean,wmean,dpert,ppert,tpert,upert,vpert,wpert,
     &   dstand,pstand,tstand,0,ptime,phgt,plat,plon,1,1,1,phidens,
     &   waverand,psmall,dsmall,tsmall,usmall,vsmall,wsmall,AmpFact)
C
C     Repeat the cycle or terminate, depending on the return value
C     of the parameter ifirst
C
      If (ifirst.eq.0)Goto 20
```

```
      If (ifirst.eq.-1)Then
C
C...     Re-initialize the velocity or position displacement values
C         (if necessary)
        ppert = 0.0
        dpert = 0.0
        tpert = 0.0
        upert = 0.0
        vpert = 0.0
        wpert = 0.0
C...     Call to gramtraj for re-initializing at beginning of next
C        Monte-Carlo profile
        Call gramtraj_E07(ifirst,ctime,chgt,clat,clon,dmean,pmean,
     &   tmean,umean,vmean,wmean,dpert,ppert,tpert,upert,vpert,wpert,
     &   dstand,pstand,tstand,0,ptime,phgt,plat,plon,1,1,1,phidens,
     &   waverand,psmall,dsmall,tsmall,usmall,vsmall,wsmall,AmpFact)
C...     Re-set initial trajectory position for next Monte-Carlo profile
        Call newpos_E07(ifirst,ptime,phgt,plat,plon,ctime,chgt,clat,
     &    clon,dctime,dchgt,dclat,dclon,0)
        Goto 20
      Endif
C
C     Terminate for any other values of ifirst
C
      End
C----------------------------------------------------------------------
```

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14. ABSTRACT
The latest version of the Earth Global Reference Atmospheric Model (Earth-GRAM2007) is presented and discussed. Earth-GRAM2007 uses either (binary) Global Upper Air Climatic Atlas (GUACA) or (ASCII) Global Gridded Upper Air Statistics (GGUAS) CD-ROM data sets, for 0-27 km altitudes. As with earlier versions, Earth-GRAM2007 provides complete geographical and altitude coverage for each month of the year. Earth-GRAM2007 uses a specially-developed data set, based on Middle Atmosphere Program (MAP) data, for 20-120 km altitudes, and NASA's 1999 version Marshall Engineering Thermosphere (MET-99) model for heights above 90 km. Fairing techniques ensure smooth transition in overlap height ranges (20-27 km and 90-120 km). Earth-GRAM2007 includes water vapor and 11 other atmospheric constituents (O_3, N_2O, CO, CH_4, CO_2, N_2, O_2, O, A, He, and H). A variable-scale perturbation model provides both large-scale (wave) and small-scale (stochastic) deviations from mean values for thermodynamic variables and horizontal and vertical wind components. The small-scale perturbation model includes improvements in representing intermittency ("patchiness"). A major feature is an option to substitute Range Reference Atmosphere (RRA) data for conventional GRAM climatology when a trajectory passes sufficiently near any RRA site. A complete user's guide for running the program, plus sample input and output, is provided. An example is provided for how to incorporate Earth-GRAM2007 as subroutines in other programs (e.g. trajectory codes).

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